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WIN! A PRIVATE SCREENING OF
THE MARTIAN FOR 50 PEOPLE

FOR DETAILS SEE PAGE 6

MATT DAMON!



Popular Mechanics

[HOW YOUR WORLD WORKS]

HOW
TO

MAKE
ANYTHING

See How They Made This Amazing
**3D
PRINTED
CAR**
PAGE 51



AMERICA'S
MAGAZINE
SINCE 1902

INCLUDING

A Bow and Arrow // A Mattress // A Smoker // A Computer
That Heats Your Home // A Bookcase in Your Wall
A Forest (With Drones!) // A Canoe // A Lampshade
One Damn Good Steak Sauce

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EXCLUSIVE
THE DISCOVERY OF THE
TITANIC!
30TH ANNIVERSARY
PAGE 92



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HOW TO MAKE ANYTHING

Literally anything. Including a canoe, a mattress, an entire forest, a table with a built-in cooler, a bow and an arrow, and damn good steak sauce.



Kerry Bishé,
fine actress
and capable
boatbuilder.



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THE CLUB

After following their story over the last six issues, we visit the young members of the auto club at Freedom High School in Freedom, Wisconsin, for the culmination of their work: the car show.

BY EZRA DYER



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LEARNING TO FLY PART FOUR: SOLO

The final installment. Up in the air all on your own.

BY JOSHUA
FERRIS



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HOW IT WORKS

The Carlsbad Desalination Project is using reverse osmosis to turn the ocean into potable water for drought-stricken California.



EXCLUSIVE

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BOB BALLARD'S ENDLESS VOYAGE

Thirty years after discovering the wreck of the *Titanic*, Robert Ballard still has a lot of ocean left.

BY RYAN
D'AGOSTINO

ON THE COVER: Local Motors' 3D-printed Strati roadster photographed for Popular Mechanics by Troy Stains.

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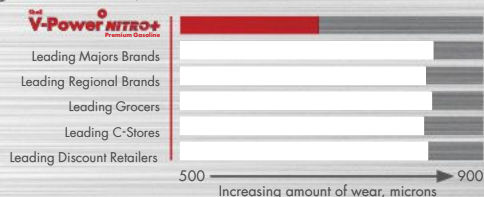


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(Results from an Industry Standard Test)



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2. Corrosion results obtained using ASTM D7548/D665.

3. Wear results obtained using gasoline-modified HFRR ASTM D6079.

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From the Editor

THE TITANIC DISCOVERY AT 30

My fifth-grade teacher, Mrs. Burns, introduced a new weekly assignment halfway through the year: current events. Each student was to bring in a clipping from the newspaper or a magazine and explain the news to the class. For my first one, that morning I tore a small item out of the local paper with my fingers—I didn't even use scissors—and brought it in, all ragged edges and ink smudges. I read it quickly and delivered an uninspired synopsis.

After, Mrs. Burns whispered to me, "Maybe you could do better next time." She knew I could.

I was humiliated, and then determined. Mrs. Burns was someone you wanted to please. I went home and looked for the coolest story I could find. There it was on the kitchen table, fresh from the mailbox: that month's fragrant, golden-rimmed issue of *National Geographic*. The headline on the cover: HOW WE FOUND TITANIC, BY ROBERT D. BALLARD. I carefully clipped every page of the story, mounted them on blue poster board, and even added some of my own illustrations. I memorized what I

was going to say. After my presentation—which was pretty captivating, if I do say so—Mrs. Burns, who was shorter than her students and older than my grandparents, pinched me on the cheek.

That day I learned a good lesson about always trying to exceed expectations. I also learned a ton about the discovery of the *Titanic*. Thirty years later, it was a privilege to be able to spend time with Dr. Ballard and find out what he's up to now. It turns out he remains one of the most dynamic, successful, and insatiable ocean explorers on the planet. The man is an inspiration. He was generous enough to allow me aboard his ship for our exclusive story (page 92) celebrating not only the 30th anniversary of his famous discovery but the long future of exploration that Ballard, who is 73, still sees ahead.

It's dedicated to Betty Burns.



With Ballard, aboard the *Nautilus*, in May.

RYAN D'AGOSTINO
Editor in Chief

PopularMechanics

SINCE 1902

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SWEEPSTAKES



A PRIVATE SCREENING!

Ridley Scott's film adaptation of Andy Weir's blockbuster man-on-Mars novel, *The Martian*, will be released October 2. But you and 49 friends can see the movie before it opens at your hometown theater in a private screening (complete with popcorn) compliments of 20th Century Fox. Go to popularmechanics.com/martian to enter.



FREE FLYING LESSONS!

Our epic, four-part story about learning to fly, written by internationally acclaimed novelist (and, now, skilled pilot) Joshua Ferris, concludes this month (page 84). In honor of Ferris's accomplishments both in the air and on the page, we want to give flying lessons to one lucky reader. Go to popularmechanics.com/flying to enter.

For rules, see page 41.



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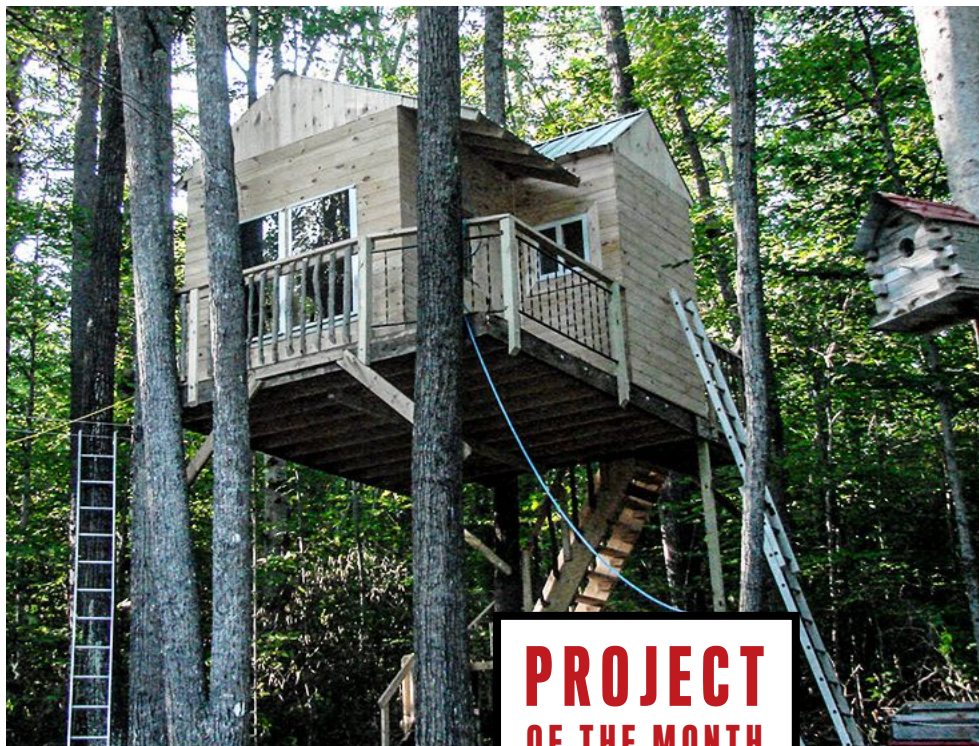
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The Reader Page

REMEMBER: We give \$100 for reader projects that we publish, and \$50 for original reader tips that we run. You can send both to editor@popularmechanics.com.



PROJECT OF THE MONTH

A TREEHOUSE RETREAT FOR RETIRED MAINERS

Richard and Louise Maki live pretty remotely out in Dixfield, Maine, on a lot abundant with sturdy old oak trees. After watching one too many episodes of *Treehouse Masters* on Animal Planet, Richard spaced out with a measuring tape a stand of oaks that would become the basis for a 16-foot-high aerial retreat for him and his wife. He had picked

up enough carpentry skills from his dad and from working construction to be able to piece the project together without plans or drawings. And without much help from anyone else, Richard, 68, and Louise, 83, set up a system of extension ladders and pulleys around the trees and put the house together over the course of three and a half months. It's fully outfitted, with two electri-

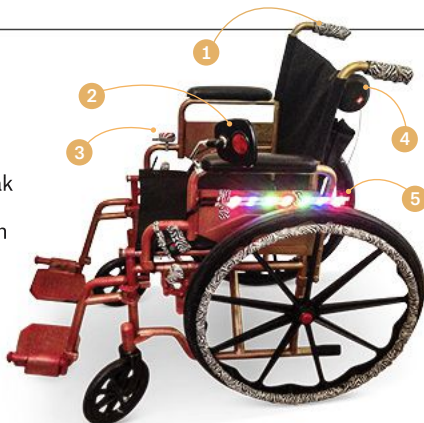
cal circuits, a small gas range, a refrigerator, a loft bed, and a TV (presumably to watch more *Treehouse Masters*). They're not quite finished with it, though. Richard wants to extend the roof over the outside landing of the treehouse so he and Louise can sit outdoors on a rainy afternoon and hear the water drum off the tin roof as they look out over their piece of the Maine woods.

BONUS!

EDITOR PROJECT OF THE MONTH

The modifications made to senior editor Jacqueline Detwiler's Drive Medical Blue Streak wheelchair as she recovers from minor leg surgery (the dangers of competitive kickball) in order from least to most extravagant:

1. Zebra-print electrical tape
2. Rearview mirror
3. Bicycle bell
4. Bluetooth speaker
5. LED lights



READER TIP!

To quickly clean a piece of metal that's greasy or caked in old paint, apply Easy-Off oven cleaner to the surface and wipe it clean.



Mark Robidoux
Coatesville, Pennsylvania

Photographed under controlled conditions. Do not attempt.

YOUR ADVENTURE AWAITS TOUGH TRUCK TIRES



WILDPEAK A/T



WILDPEAK H/T



WILDPEAK M/T
COMING SOON

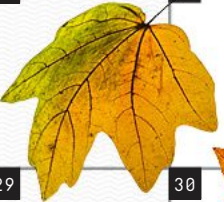
WILDPEAK

WILDPEAK Tough Truck Tires take you everywhere a new experience awaits, with confidence and comfort.

FALKEN
TIRE
ON THE PULSE

Calendar / SEPTEMBER

How to get the most out of your month.

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	TURDAY
		1 If you haven't yet, upgrade to Windows 10. The new and improved OS with Xbox Live built in is free for Windows 7 and 8 users.	2 The cinematic version of one of your dad's favorite books, Bill Bryson's <i>A Walk in the Woods</i> , opens.	3 College football season gets underway tonight with the University of Michigan in a cupcake game against Utah.	4 	
6 The 100th anniversary of the introduction of the tank.	7 Labor Day. 	8 The October issue of <i>Popular Mechanics</i> hits newsstands.	9 For those on the Eastern Seaboard, it's the thick of hurricane season, a good time to check and tune your backup generator.	10 The Steelers go against a Brady-less Patriots to kick off the NFL season.	11	12 As the weather finally cools, refurbish your lawn: Till any damaged spots, reseed them, and put down a starter fertilizer.
13 U.S. Open men's final: Catch a view of Arthur Ashe Stadium in mid-construction of its retractable roof. And some tennis.	14 	15 Yes, you can still go to the beach after Labor Day.	16 Wednesday night crab bash! See page 35 on how to pull it off. 	17 	18 Two true-story movies premiere: <i>Everest</i> , and <i>Pawn Sacrifice</i> , about chess prodigy Bobby Fischer.	19 Oktoberfest begins in Germany. Celebrate domestically. 
20 The Emmy Awards offer one final opportunity to pontificate about <i>Mad Men</i> . 	21	22 	23 	24 Now's a good time to seal your deck in preparation for the rain and winter snow to come.	25	26
27	28 	29 Ahead of the rain and leaves of the fall, get up on the extension ladder to check on your gutters and attend to any repairs.	30			



THIS MONTH IN MECHANICAL HISTORY

Little Willie, the prototype of the first tank, which would change warfare in World War I, came off the line in 1915 with U.S.-made tracks and running gear. Given the derisive nickname of Germany's crown prince, the tank got stuck in ditches and topped out at a speed of 2 mph. British engineers fine-tuned the tracks, and a fighting version of the tank was ready for battle in 1916.



IN NEXT MONTH'S ISSUE

October's *Popular Mechanics* features our annual blockbuster home-improvement spectacular.



THE MOVIE RECOMMENDATION: Everest

Director Baltasar Kormákur took stars Jake Gyllenhaal and Josh Brolin to the base camp of the world's highest peak to film this adventure epic. The movie follows the 1996 disaster on the mountain that left eight explorers dead and became the basis for Jon Krakauer's classic book *Into Thin Air*. The film's crew was shooting on location in April last year when a deadly avalanche struck a nearby camp.



AMERICAN-MADE GERMAN-STYLE BEER

Plenty of American craft brewers make fantastic ales and pilsners that rival what revelers will be downing in Munich. Sierra Nevada makes the easy-drinking Nooner, a German-style pilsner, out of its Chico, California, brewery.



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Letters

THE READER MOST QUALIFIED TO WRITE A SONNET ON HAMMER DRILLS

I'm a 28-year-old poet who has recently started reading Popular Mechanics. My father gave me a copy when I expressed frustration at not knowing how to fix anything. The June issue not only taught me some tricks of the trade but I also learned how creative mechanics can be, as seen in the work done by the makers who remade your logo ("Four Makers, Four Logos"). Now I'm seeking work as a handyperson to get some on-the-job training and am looking forward to developing my skills both in writing and mechanics.

Diane Bitler

New York



BOB CARLSON'S AUTO SHOP CLASS CERTAINLY DIDN'T TEACH VAN HALEN HOW TO USE A ROUTER

What a shame that when he attended Pasadena High School, Eddie Van Halen ("Eddie Van Halen Is God," June) chose to take auto shop with Bob Carlson rather than my woodworking class.

Ralph Bush

Arroyo Grande, California

THIS MARK GUY MUST BE GETTING CONFUSED

I disagree with one of the Shop Rules in the June issue ("The Ultimate Workshop"). "Think. Measure. Mark. Think. Cut." It ought to read, "Think. Measure. Mark. Think. Measure. Cut."

Elliot Ofsowitz

Sarasota, Florida

WHICH COVER IS WEIRDER?

This month's contenders:

A October 1933



B October 1946



Cast your vote now for cover A or cover B! The winning cover will square off against another challenger next month.

- Email your vote to editor@popularmechanics.com.
- Or tweet your vote to @popmech using #weirdcover.
- Or tag us on Facebook [@popularmechanics] using hashtag #weirdcover.

WHAT A 13-YEAR-OLD AND AN ACCOMPLISHED NOVELIST HAVE IN COMMON

I am 13, and flying is my passion. As I am also taking flight lessons I have thoroughly enjoyed reading the four-part series "Learning to Fly" [for the final installment, turn to page 84] and Joshua Ferris's journey to a solo flight. Thanks for the wonderful story.

Will Monin

Decatur, Alabama

THEY START THEM YOUNG IN MICHIGAN

My father was reading an old issue of Popular Mechanics while babysitting my three-year-old son, Dean, who likes to be like his Papa. So, Dean put on his Papa's glasses, picked up Papa's magazine, and decided to have a read.

Erica Thomas

Saginaw, Michigan



IF EMAIL ISN'T YOUR THING

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Great New Stuff

The things you need in your life this month.



The innermost lining has space between segments so it'll conform to different head shapes while allowing for air from the nine intake vents to flow through.

01

BELL MOTO-9 FLEX MOTORCYCLE HELMET

You always want the best technology, especially when it comes to cushioning your head. Typical motorcycle helmets are a simple foam structure inside a shell, constructed to absorb the force of a high-speed crash. But head injuries can occur at any speed, which is why the Flex has three layers of materials. Each has a different density designed to protect your *cabeza*, no matter the speed of impact. The outer layers can also slide around the inner layer, which diffuses rotational energy that can cause concussions. **\$650**

02

UCO TITAN STORMPROOF MATCHES

They'll burn through wind, snow, and rain, even after being completely submersed. **\$10**

03

SPACEX MARS POSTERS

Elon Musk changed electric cars, rockets, and now, wall art? SpaceX just came out with three great retro posters advertising geographic features of Mars as tourist destinations. The high-resolution files can be printed by anyone with the inclination. Just be sure to use the good paper. **Free**



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WOLVERINE 
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THE CODE



Popular Mechanics has partnered with Ford to bring you The Code, an editorial program inspired by the all-new 2015 Ford F-150, and the men who drive them. From the skills every man should have and the latest in gear to smart news and entertainment, The Code brings the spirit of “Built Ford Tough” to life.



MEET THE AIR FORCE'S MOST ELITE UNIT

Pararescue jumpers—a.k.a. PJs—are the most elite unit in the U.S. Air Force, and perhaps the least well-known special operations team on earth. PJs are trained to recover and provide medical care in the harshest and most dangerous environments. You'll know them by their maroon berets, which signify that they've completed the grueling two-year training program—sometimes called “Superman School.”

READ THE COMPLETE STORY AT POPULARMECHANICS.COM/THECODE

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- ▶ **Tough Jobs: Long-haul Trucker**

DROUGHT HACKING: HOW TO WASH YOUR CAR WITH A SINGLE CUP OF WATER



BREAK DOWN THE DIRT

Don't just take a hose and sponge to your truck; instead use with a water-based, eco-friendly cleaner to break the dirt down.



LIFT IT OFF

Rather than using an old rag that will likely just spread the dirt around, use a high quality microfiber towel to lift the loosened dirt off.



FORGET THE HOSE

A garden hose pumps out 10 gallons a minute. Save water and prevent streaks by using a spray bottle and just a cup of water. It's what the pros do, and Mother Nature will thank you.



CLEAN REGULARLY

Prevent serious dirt buildup by cleaning your car at least once every other week. A few minutes here and there will save you time and elbow grease in the long run.

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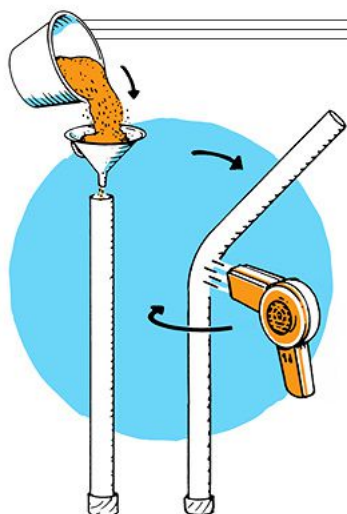
Shop Notes

EASY
WAYS TO
DO HARD
THINGS



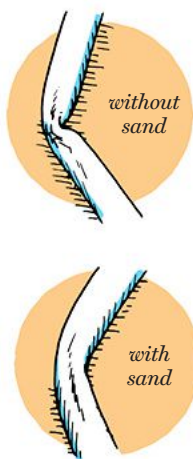
A Common Clothes Iron Repairs Unsightly Dents

DROPPING A HEAVY TOOL on good lumber can leave a nasty dent. To fix it, drip some water on the dent and let the wood soak it up. Place a shirt over the damp area and use a clothes iron on its medium-high setting to apply heat. The wood will swell with the moisture. Repeat until the dent is gone. Sand smooth. Note: Does not work for heavy tools dropped on toes.



Bend PVC Pipe Into Shape Without Breaking It

Phil Crockett of the Phil Crockett YouTube channel found an easy way to bend PVC pipe without kinking or breaking it. Use duct tape to seal one end. Fill the pipe with sand. Heat with a hair dryer until the pipe is pliable, then bend as desired. The sand keeps kinks out—the pipe cools with a nice, smooth bend.



SAWDUST THREE WAYS

Uses for sawdust, in ascending order of granularity.



COARSE

After a spill in the workshop or garage—think: pool of motor oil—a sprinkling of sawdust will absorb the liquid and aid cleanup.



MEDIUM

Rub hands with sawdust to remove grease. And exfoliate.



FINE

To create wood filler, mix sawdust with two-part epoxy.

HAMMERING NAILS IN TRICKY SPOTS

Sometimes a nail needs to go where it's difficult to hold it. In such a place, put a small ball of putty on the wall. Stick the point of the nail into the putty, which holds it. Hammer away.

To Fix a Door That Sticks

First determine where the door is contacting the jamb: Turn on the lights on one side of the door. Leave the other side dark. Standing on the dark side, note the light that outlines the door. The door sticks where the light is blocked. For a severe stick, remove the door and shave with a planer. For a non-severe stick, keep the door in place and use a paint scraper to relieve the doorjamb.



To Still a Door That Always Swings Shut

Add friction to one of the door's hinges: Remove a hinge pin. Lay it on the floor and tap it with a hammer until it develops a minor bend. Put it back in the hinge.

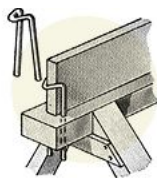


FROM
—THE—
ARCHIVES
(1970!)

Stiff Bristles Store Sharp Points

Constantly reaching for the same small tools? Stashing them point down in the bristles of an overturned scrub brush keeps tools handy and hands safe. Works best if files have handles on them.

FROM
—THE—
ARCHIVES
(1964!)



Easy Sawhorse Improvement

A sawhorse becomes handier if it can hold boards upright. A removable bracket formed from steel rod will do the trick. Put a U-shaped bend in the middle, wide enough to hold a board. Bend the ends down parallel to each other. Holes drilled in the sawhorse hold the bracket in place.



We are always looking for clever solutions to everyday problems. Email your shop notes to editor@popularmechanics.com and we'll pay \$50 if we print them.

Common Currency Indispensable for Chainsaw Maintenance

For optimal cutting performance, keep the groove on a chainsaw's guide bar uniform and clean. Pocket change is a surprising aid. The three most common saw-chain gauges—a measurement of the width of the chain's drive links—are 0.050 inch, 0.058 inch, and 0.063 inch. These match the width of dimes, pennies, and nickels, respectively. To test for wear, slip the appropriate coin into the slot on the guide bar. If it can wiggle side to side, the groove is worn. A dime is also an effective cleaning tool, as its rough edge picks up gunk and debris.

QUICK SUBSTITUTE FOR LOST CAP

In a pinch, a twist-on electrical-wire connector can replace the missing cap from a bottle of glue.



Spare Parts for Hanging Coats

Screw a shelf bracket to the back of the closet door and affix a short length of chain to each end of it. Hangers slip through the links in the chain.

The Right Screw for the Job

Picking out an appropriate screw is complicated. This handy guide explains the sizes, shapes, and types you might encounter.

DRIVE TYPES



FLAT-HEAD
The original.



PHILLIPS
Centers the driver.



COMBINATION
Flat-head and Phillips.



SQUARE
Prevents cam-out (driver slippage).



STAR (TORX)
Protects fastener head.

HEAD TYPES



FLAT



ROUND



PAN



OVAL



HEX

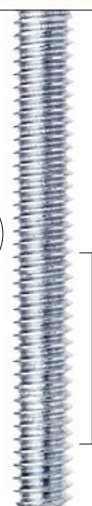


HEX WASHER

SCREW TYPES



LENGTH
On a wood screw, measured from the tip to the fastening surface; on all others from the tip to just under the head.



THREAD COUNT
The number of threads in 1 inch. Used in the U.S.



THREAD-CUTTING MACHINE SCREW
Creates its threads as it is driven.



SHEET-METAL SCREW
Pointed. Used with sheet metal.



DIAMETER
Measured from the edges of the threads.

SELF-DRILLING SHEET-METAL SCREW
Drill-like point to drill through sheet metal.



LAG SCREW
Used with wood, typically larger than wood screws.

With thanks to: Jason Bourque of Bolt Depot, for fastener wisdom, and Cary Shepherd of Husqvarna, for sparing some change for our chainsaws.

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HOW YOUR WORLD WORKS

THE GREAT WORLDWIDE CANAL RACE

The two most famous canals—and an upstart—battle to move the biggest ships in global trade.

BY KEVIN DUPZYK

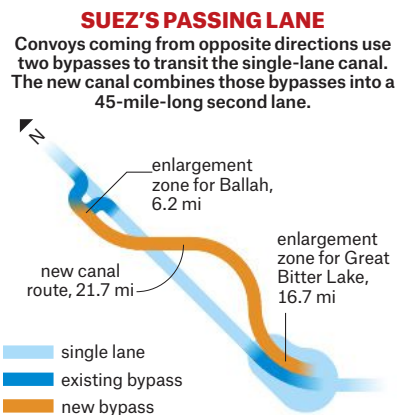
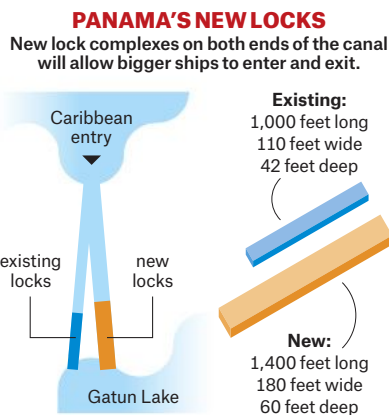
Since this photo of the Panama Canal's new Atlantic lock was taken (in December), engineers have allowed water to enter the structure.

PHOTOGRAPH BY TOM FOWLKS

POPULAR MECHANICS _ SEPTEMBER 2015 21

In 1984 about a million tons of cargo passed through the Suez Canal every day. Last year that number was up to 2.6 million. Over the same period, the number of ships traversing the canal every day dropped, from more than 21,000 to about 17,000. How? The ships got bigger. The highest-capacity container ship at sea today holds more than four times as much cargo as the record holder in 1984. With global demand for imported goods increasing, companies employ the cost-effective strategy of cramming everything on large vessels and making fewer trips.

Problem is, the Suez Canal and its Western Hemisphere counterpart, the Panama Canal, were not designed to accommodate enormous ships, which have grown in three measurements: length, width (called beam), and depth in the water (draft). Both canals are scrambling to accommodate the deeper drafts of megaships, which can reach more than 50 feet. The Suez's main canal can move behemoth container ships, with beams up to 164 feet, but only in one direction at a time. Panama's famed lock system is too small in all three dimensions. Built in 1869 and 1914, respectively, both waterways require updates if they're to remain competitive with each other. And with a new canal scheduled to open in Nicaragua within



the next five years, they need to act quickly. Lucrative shipments from Southeast Asia to American ports on the Gulf and the East Coast could travel on any of the three routes.

The Panama Canal has aged more poorly because of its dependence on locks, which raise ships 85 feet on entry and lower them back to sea level at the exit. The current locks can handle ships with capacities of up to 5,000 20-foot equivalent units (TEUs, each about the size of a half-length semi-trailer). The world's largest container ship, the MSC *Oscar*, carries nearly 20,000 TEUs. To expand the canal, workers are deepening and widening the existing route and constructing new locks from 16 rolling metal gates. When completed in April 2016, the new Panama Canal will be able to handle ships of up to 13,000 TEUs—ships longer than a Manhattan city block, with an eight-story building of containers piled on deck.

Suez is simpler, lock-free, and large enough to handle oversize ships, but only if they transit in convoys, with bypasses allowing the convoys to pass one another. To allow more room, workers are digging a new canal parallel to 22 miles of the existing one and expanding the current bypasses. The result will be a new 45-mile lane, expected to open this fall, that should reduce ships' journeys by at least 12 hours.

Even when the revisions are complete, however, both Suez and Panama will still be limited. Panama's new locks won't be able to handle ships the size of the *Oscar*, and Suez will still be mostly one-way. This is what makes the Nicaragua contender so potentially world-changing. In December 2014 a Chinese company, HKND Group, announced a design for a canal that could handle *all* of today's megaships. A route has already been selected—about 300 miles north of the canal in Panama. The Nicaraguan government has given its blessing.

Plenty of people, including Eric Farnsworth, vice president at the Council of the Americas, an organization that supports business development in the Western Hemisphere, are dubious that the Nicaragua Canal will actually be completed, freighted as it is with economic and political baggage. But grant that it's up and running in five years, as HKND Group claims, and suddenly the Panama Canal would have to compete directly with a canal built using an additional century's worth of technology.

Last September Egypt commemorated its Suez Canal project with a set of stamps. One depicted the Panama Canal. To Egyptians it was an honest mistake. To Panamanians, a laugh. To the Chinese, prescient. Consumers don't care. To most of us, canals, like stamps, are just a means to get stuff. To the countries that design and maintain the mighty canals of the world, a single waterway can contribute between 2 percent (Egypt) and 6 percent (Panama) to the economy. Their demise could destabilize a nation. You can be sure the race to improve their technology will be heated.

HOW TO CHOOSE A SHIPPING ROUTE

When planning a trip from a Vietnam factory to a Chicago store, a hypothetical shipper must consider many factors, including tariffs, canal fees, boat size, load size, and required unloading equipment.

ROUTE 1

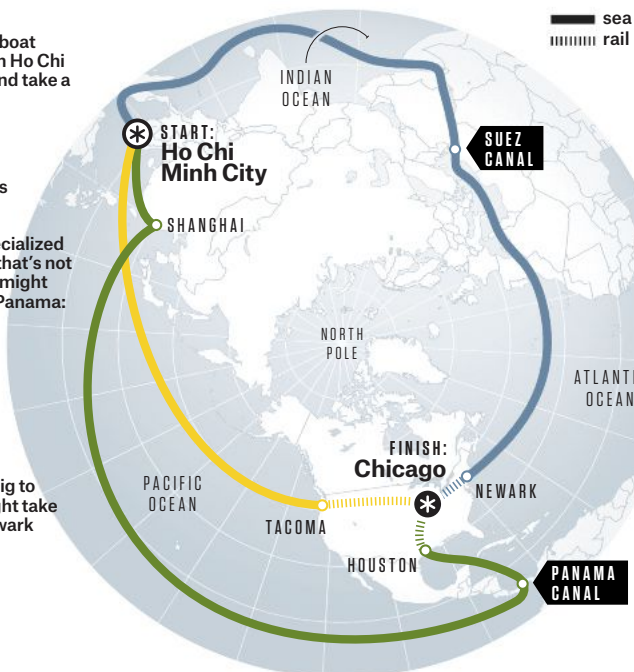
In the simplest case, a boat could travel direct from Ho Chi Minh City to Tacoma and take a train from there:
18 days to Tacoma
3 days unloading
4 days 12 hours by rail
TOTAL: Approx. 25.5 days

ROUTE 2

If the load requires specialized unloading equipment that's not available in Tacoma, it might transit to Houston via Panama:
6 days to Shanghai
2-day layover
23 days to Houston
1 day unloading
3 days 1 hour by rail
TOTAL: Approx. 35 days

ROUTE 3

Unless the boat's too big to fit, in which case it might take a westerly route to Newark through the Suez:
36 days to Newark
2 days unloading
2 days 17 hours by rail
TOTAL: Approx. 41 days



WELCOME HOME THE BRAVE

A black silhouette of a soldier in full combat gear, including a helmet and a rifle, walking towards the right. The soldier is positioned within the letter 'A' of the word 'BRAVE' in the main title.

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THE BURNT LIME GIMLET

Place a halved lime in an ungreased pan cut-side down over high heat. Sear until the sliced ends are caramelized, about 3 minutes. Juice the lime while it's still hot and run the juice through a double tea strainer, then a wet coffee strainer, to clarify. Pour 1 ounce lime juice, 2 ounces Hayman's Royal Dock Navy Strength gin, ½ ounce simple syrup, and a dash orange bitters into a cocktail shaker with ice and shake. Strain and serve in a martini glass.

Though every cocktail and, in fact, every bartender, is a little different, the ratio of two parts liquor to one part sour to one (or one-half) part sweet is a common one for sour-style drinks such as the daiquiri and the margarita. The acid brightens the drink, making it feel more refreshing and less heavy. According to Darcy Gentleman at the American Chemical Society, along with counteracting sugar so that the drink isn't too sweet, acid helps flavors blend in alcoholic drinks. If you want to taste all the flavors in every sip, you need a little acid.

Learning how and in what ratio to pair sour juices with liquors has always been a primary challenge of bartending. Lemons have a stronger flavor than limes, and pair well with beefier base notes—rye whiskies and punchier gins. Orange and grapefruit juices contain sugar as well as acid, and can replace elements of both sweet and sour. You could rim a glass with powdered citric acid. You could replace juices with so-called drinking vinegars (also known as shrubs) to add acetic acid instead of the acids common in citrus fruits. You could replace the sweet element with liqueurs. The only thing you can't do is ignore the acid-sugar balance.

You can even change the acids themselves. That's why Todd Maul, bar director and partner at Café ArtScience in Cambridge, Massachusetts, decided to buy a centrifuge. After a few minutes at 10,000 rpm to skim out the impurities and sediment, Maul says, his lime juice is lighter, brighter, and drier-tasting. It lasts six times as long in the refrigerator. What you get is clarified lime juice, with the extreme sour notes removed. This reduces the need for complementary sugars, allowing for more of the liquor's base flavor to shine through. Which means you get a mellower drink. "It's like listening to Miles Davis instead of the Ramones, where everyone is playing as loud as they can to be heard," Maul says. "You don't have to fight with it."

You could buy your own centrifuge (\$150 to \$300 on eBay), but Maul has an easier way to change the effects of your acids at home. Sear your limes in a skillet, then juice them and pass the juice through a coffee strainer to remove any solids. By adding heat, you're caramelizing the natural sugars in the limes to counter the acidity. This also adds an earthy, smoky flavor—possibly the key to your new signature gimlet.

HOW TO USE ACID*

Bartenders are experimenting with new ways to manipulate a classic cocktail element. You can too.

BY PETER MARTIN

There's a reason a daiquiri tastes good and Long Island iced tea tastes terrible: balance. (Also: self-respect.) Of the many, many ways a cocktail can go wrong, poor acid balance is among the most common. In the case of sours, Collinses, and smashes, three types of cocktails that rely heavily on citrus, it's a bartender's job to make sure the liquor, sugar, and acid play well together. It's like a boozy game of rock-paper-scissors in which you're always pulling for a tie.

*IN A COCKTAIL.
THIS ISN'T
THAT KIND OF
MAGAZINE.

THINGS YOU
MIGHT ENCOUNTER
AT THE BAR:
CANE-JUICE
EXTRACTOR



Order a mojito at Asia de Cuba restaurant in New York City and you may notice a 100-pound machine whirring away behind the bartender. This is the bar's sugarcane-juice extractor, which uses three rotating cylinders to crush an 8-inch stalk of sugarcane into 2 ounces of juice in just five seconds. The bar uses this juice, which has a vegetal, diluted sweetness similar to that of coconut water, in addition to simple syrup. It adds both sugar and flavor to cocktails, and gives customers something to talk about.

—KATIE MACDONALD



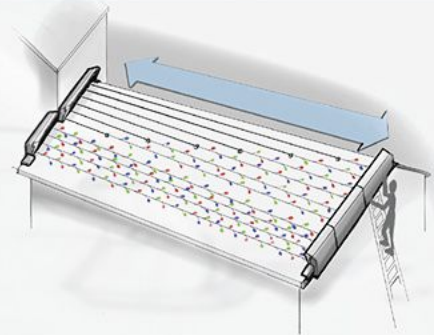
INSPIRED

Industrial Design students find inspiration in a faucet.

Using Moen's Reflex self-retracting pulldown faucet as inspiration, Savannah College of Art and Design students were challenged to invent other things that put themselves away. Here are a few of their designs. [#InspiredByReflex](#)



SELF-RETRACTING HOLIDAY LIGHTS



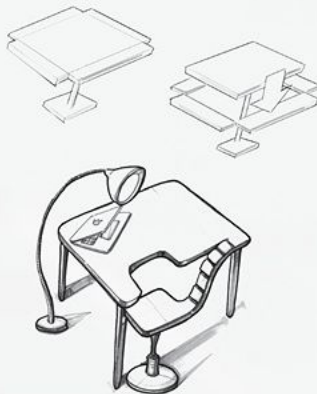
To keep holiday lights from getting all tangled up, one group of students invented a housing unit that can be placed on the side of a house, for example. Just pull the lights out. Then, when the holidays are over, the lights self-retract back into the unit until next season.



Prototype in beta staging for Holiday Lights Retractor

SELF-RETRACTING TABLE AND CHAIR

Another group of students set out to solve the age-old problem of people not pushing their chairs back under the table when they get up to leave. You just push the chair down and an air pump automatically retracts it back under the table where it belongs.



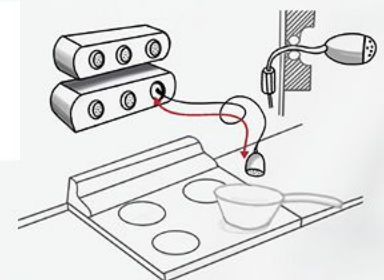
Prototype testing for Retractable Table

SELF-RETRACTING SPICE RACK

A third group of students found a way to help chefs keep their counters tidy—a self-retracting, wall-mounted spice rack. Pull a spice out to use it. Let it go, and it automatically retracts back into place.



Spice Retractor prototype



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THE DOCTOR WHO WOULD BE PRESIDENT

Taking a scalpel to a living brain requires a superhuman amount of confidence. Perhaps that's why Ben Carson, a retired neurosurgeon with no shortage of audacious opinions, believes he can win the Republican nomination and become the first medical doctor in the White House.

INTERVIEW BY MATT GOULET

POPULAR MECHANICS: To start, I have to ask the obvious question: How do you think being a surgeon would prepare you to be president of the United States?

BEN CARSON: The thing that has helped me is being faced with a lot of supposedly impossible situations—things that people said can't be done. What I would do in those situations is say, well, that's probably true. But maybe we could look at some other ways of doing it. I recognized early on that it's important to be able to bring in people with other perspectives. If you can amalgamate their energies and their intellect, you'll be much further ahead than if you're trying to come up with all the answers yourself.

PM: You've come up with a couple of right answers yourself, though. You convinced a bunch of doctors to give conjoined twins hypothermia to save them.

BC: The first set of conjoined twins I sepa-

rated, I sat down with people and I said, if we use hypothermic arrest at the critical time in the operation, we could avoid having the patients bleed to death. I just talked about how exactly that would work. When people heard it, they agreed. It's a matter of being able to explain things in a way people can easily understand in order to gain their support. And I think the same is true when you're leading a nation. The majority of people in our country don't understand what the fiscal gap is. You have to be able to explain that in a way that they get it.

PM: Do you have any strategies for dealing with the times when people don't get it?

BC: You always have to be in active mode, thinking about what works and what doesn't work. I've learned that there's certain language that doesn't allow people to actually hear what you're saying because they're just concentrating on the words that you've said. I've learned how to moderate that so I can get the message out without distracting people with the words.

PM: Does it frustrate you to hear people say that because a president can't decide to become a surgeon tomorrow, someone like you shouldn't be able to decide to be president?

BC: It's frustrating in the sense that people who say things like that have very little understanding of what is required to be a neurosurgeon versus what is required

to engage in the political sphere. They're two completely different skill sets. A lot of people want you to believe that you can only run things in government if you have detailed knowledge of all the nuts and bolts of everything. I completely disagree.

PM: When you retired from neurosurgery in 2013, where did you leave the field? What's going on now that's really cool?

BC: What's going to be extremely cool going forward is the integration of robotics into the whole process. Robots are much more precise than humans, no matter how good the humans are. They can magnify things so that vessels that are normally just a few millimeters apart look like there's a mile between them. Robots are being integrated into urology and cardiothoracic surgery. The instruments aren't quite delicate and fine enough yet for neurosurgery. But they're coming.

PM: That's interesting coming from someone who titled his autobiography *Gifted Hands*. You're okay with ceding control to a robot?

BC: Somebody will still have to control the robot. And you will have to know what you're doing to control it. But, you know, it's progress. It's just like flying an airplane. People fly 747s, but they don't do much of the flying anymore. The computer does it. But they better know what the heck they're doing nonetheless.

HOW TO MAKE A PRESIDENT

Ideally, in a democratic race, the people choose the candidate based mostly on his or her platform.
In real life, there are a few traits that winners have in common.



Be a man
EVERY
PRESIDENT



Be or
have been
married
42 PRESIDENTS



Be clean-
shaven
30 PRESIDENTS



Have blue
eyes
28 PRESIDENTS



Don't serve as
vice president
beforehand
29 PRESIDENTS



Do serve in
Congress
26 PRESIDENTS,
19 IN THE
HOUSE ALONE



Work as a
lawyer
25 PRESIDENTS



Have a net
worth of
\$1 million to
\$10 million
14 PRESIDENTS



Have an
Ivy League
bachelor's
degree
11 PRESIDENTS



Be born in
Virginia
8 PRESIDENTS





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A BETTER JAIL

The latest group to try to fix the broken penal system in the U.S. is . . . architects?

If you've ever been to Las Vegas, you know that environment can manipulate behavior, encouraging you to stay out later or spend more money without realizing it. It's the same in prison: Depressing conditions and a draconian culture can encourage poor behavior, which leads to longer punishments—at taxpayers' expense. Prison is meant to deter crime, not foment it. For this reason, two architecture firms, KMD and HMC, used design principles from colleges and hospitals to build a women's jail in San Diego that could reduce assault, vandalism, and, eventually, recidivism. "It's not nice. It's not like you're in a luxury hotel," says Richard Wener, an environmental psychologist at New York University. "But there are colors. There's furniture. It says, 'We expect you to treat this place with respect. If you don't, you won't be able to stay here.'" Though the \$268 million Las Colinas Detention and Reentry Facility's first phase has been open for only a year, both inmates and staff have already reported positive responses to the design. Here's how the architects did it. —JACQUELINE DETWILER

1. Large windows

Both natural light and views of the outdoors reduce stress, according to environmental psychology studies. Lack of light may contribute to insomnia and mood disorders in prison populations, which can lead to behavioral problems that might not have manifested otherwise.

2. Sound attenuation

The architects worked with an acoustics expert to reduce noise and echoing in common areas, which can increase stress and confrontations. This was especially important in the cafeteria,

where suspended "acoustical clouds" high above the tables muffle noise. "There's evidence that the effects of stress are cumulative," says Wener. When you've got lack of sleep, bad odors, insufficient light, and constant noise, the noise is an easy first target.

3. Campus-style housing

Living areas in the jail's lowest-security settings look much like a community of two-story homes surrounded by outdoor areas, such as an amphitheater. Inmates have personal space in the form of their own cubicles. The goal is not to make life fun, it's to reduce bad behavior, which leads to extended stays

and overcrowding. "Every time we go into a building, we read the environment, and it tells us what's expected of us," says Wener.

4. Open booking

Las Colinas' open booking area is more like a large doctor's office than the standard tank that prisoners are tossed into. "When you're in a mixed room, and you feel like there are a lot of dangerous people around and they're gonna assault you, you have only a few options, and none of them are good," says Wener. "In open booking, the worst thing that happens is prisoners get bored for a few hours."

5. Integrated guard areas

Instead of observing inmates through windows, Las Colinas deputies are stationed inside the living units. You have the



A standard county detention facility has towers and windows or bars that separate staff from inmates, small windows that don't let in much light, and drab institutional colors.

same number of guards, but they're in closer proximity. "It's analogous in some ways to community policing," says Wener. "It's the cop on the beat instead of driving by in the car. And the surprising thing for lots of people is that the safety record of officers is as good or better than in traditional jails, even though there are no bars between them and the inmates."



TABLETS FOR INMATES

One reason many inmates return to prison after release is that they aren't able to develop technology skills while serving their sentence. Jail Education Solutions is working to change that. The company's incentive-based learning platform, Edovo, uses tablets to provide therapy, classes, and certifications to inmates. Like other educational apps, Edovo even offers rewards for completed programs. If an inmate spends three hours on a prep course for a general education diploma, he might earn enough credits to watch *Avatar*. —CAMERON JOHNSON

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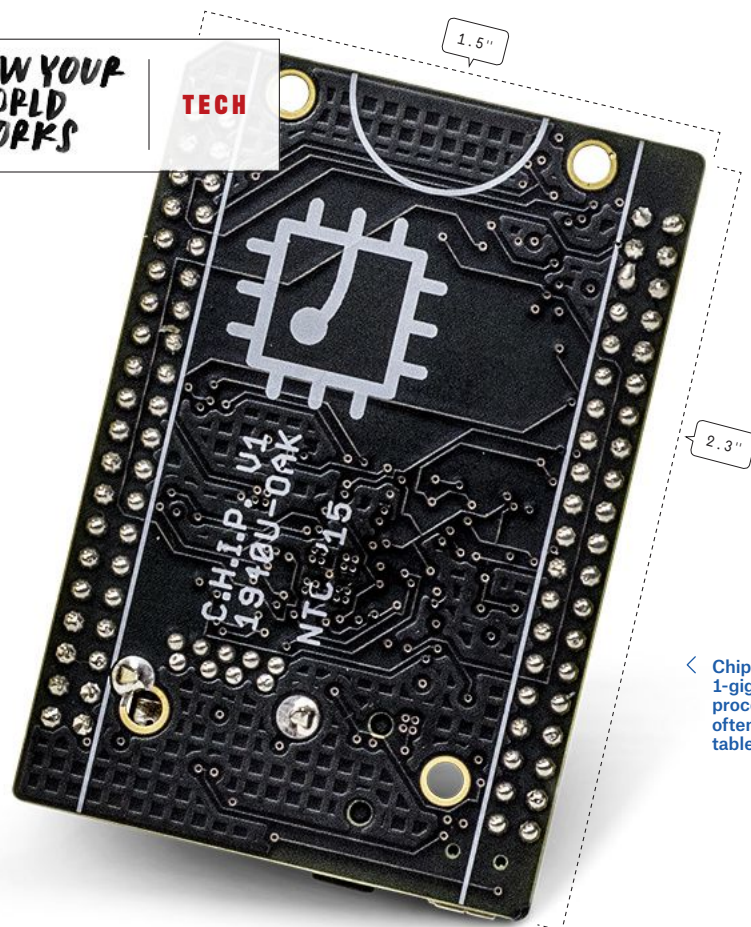
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FUEL SYSTEM

MAXIMIZE
FUEL ECONOMY

SMOOTH IDLE

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CONVERSATION STARTERS FOR NERDS

Apple initially resisted turning the logo on its laptops upside down (so it's upright when open) because the designers thought people would try to open the shell the wrong way.

number of dreamers who might create a new product. An enterprising maker could use Chip to do any number of the things computers do: retrofit cabinet speakers to blast a playlist, build a Super Nintendo, or make appliances turn on and off with the sound of his or her voice. With the addition of a few sensors, a Chip could be made into a biometrics monitor that sends patient data over Wi-Fi.

But there is always a "but." Chip runs Debian Linux, a free operating system maintained by programmers working pro bono for fellow builders. Debian Linux is complicated enough that Chip's developers anticipate a learning curve.

< **Chip runs on a 1-gigahertz R8 ARM processor, the kind often found in cheap tablets sold in China.**

"Chip ships with Scratch, a learn-to-code software," says industrial designer and Next Thing Co. founder Thomas Deckert. With access to You-

Tube tutorials and a second computer for copying and pasting large chunks of code, sure, a determined amateur could learn quickly. Anyone else is in for a lot of work.

So what will Chip do for those of us who are content to interact with icons and pull-down menus? It's unlikely to bring modernity to impoverished areas—the Wi-Fi-equipped boards need infrastructure to function. It's not durable enough to be used in commercial devices, either. The hope is that by untethering technological innovation from the need for heavy investment, Chip will create more makers. "You can make prototypes that you may turn into a business," says Stuart Lipoff, a consumer electronics consultant for the Institute of Electrical and Electronics Engineers. "Chip enables a broader range of creative minds to come up with ideas." So even if you're not the one actually writing the code for an industry-changing medical diagnostic device or an app-activated security system, there is a solid chance that some kid out there with a garage, a little coding ability, and nine bucks will use Chip to create something that will make your life better.

CAN A \$9 COMPUTER CHANGE THE WORLD?

Call it the microwave effect: A newer, cheaper circuit board could democratize computer-powered devices. All it needs are a few determined handlers.

BY ALEXANDER GEORGE

If you distill a computer down to its essential parts, there's not much there. Get rid of the display, the casing, and all the software, and you're left with a central processing unit, some memory, and a few familiar ports: a scary-looking board most of us wouldn't know what to do with. In 2012 the world was introduced to the Raspberry Pi, a stripped-down computer that sells for around \$40. Later this year a

group of engineers in Oakland, California, will release an even cheaper version: Chip, a credit-card-sized circuit board. The price: nine dollars.

Chip feels egalitarian. Rebellious, even. The engineers, known collectively as Next Thing Co., are working with a manufacturer of inexpensive Chinese semiconductors in order to sell the computers for next to nothing, with the goal of reaching the greatest



Frederique Constant Horological Smart Watch
\$1,295



Mondaine Helvetica No. 1 Smart Watch
\$950



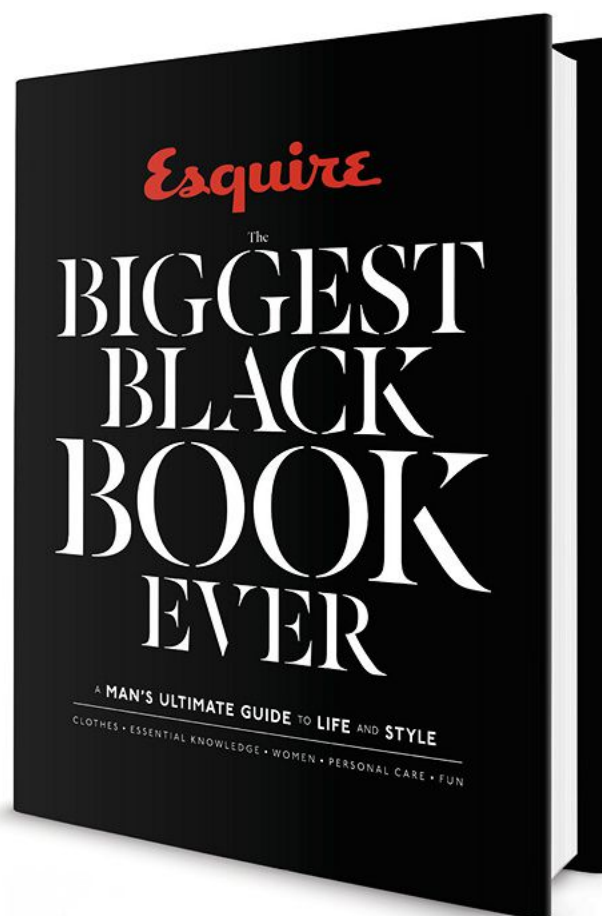
Alpina Horological Smart Watch
\$1,150

FANCY WATCHES GET SMART

A smart watch may help you get in shape and sleep better, but underneath a fancy cuff link, a beeping, glowing bracelet can look . . . out of place. So, for people who want to record their footsteps while attending a black-tie benefit, several classic watch brands have now fitted transmitters and activity sensors, the same found in Jawbone's and Nike's fitness trackers, into traditional analog designs. Quartz models from Frederique Constant, Alpina, and Mondaine look like heirloom timepieces, but they can count steps, send the information to your phone, and wake you up with a silent vibration alarm. Best of all, with no big display to power, the batteries last two years before they need to be replaced.

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Q

WHAT'S THE LIKELIHOOD

THAT INNOVATIONS IN ENERGY
PRODUCTION AND VEHICLE
EFFICIENCY HAVE BEEN QUASHED
BY CORPORATIONS BEFORE SEEING
THE LIGHT OF DAY?

A

WHAT'S THE LIKELIHOOD that a bear... Actually, there are two levels to this one. There's the paranoid, urban-legend take that promulgates fantasies about the suppression of inventions like muscle cars that run on a thimbleful of water. Then there is reality, which acknowledges that big corporations are, by their nature, self-interested and not above a certain degree of, shall we say, chicanery when it comes to defending their competitive positions.

During the 1930s and '40s, a consortium of companies including General Motors, Firestone Tire, and Standard Oil bought up and shut down streetcar systems in a number of American cities in a bid to force public transit toward the use of gasoline-burning, tire-using buses. GM and several others were convicted of conspiring to monopolize public transportation, but got off with paltry fines. More recently, attention has centered on GM's introduction—and abrupt withdrawal—of an electric car during the 1990s. The brief and smashing success of the EV1, as it was known, spurred research and production of electric and hybrid vehicles by others and arguably led to the advent of the Toyota Prius, so any impure impulse there may have, ahem, backfired.

Mostly, though, corporations defend their interests through good old-fashioned, completely legal palm-greas... er, lobbying, seeking to influence public-policy decisions in ways that favor their businesses and disadvantage others. As David Keith, professor of applied physics and public policy at Harvard, puts it, "Businesses don't require conspiracy, because their interests are clear. Everyone expects regular coal-fired generators to lobby against solar and wind power. And they do." Does this mean that certain promising, nascent technologies may be challenged or even strangled? Does a bear...

The cold water out of my bathroom tap is always much colder than the cold water out of my kitchen tap. Is this a common phenomenon?

It is indeed common for water temperature to vary from tap to tap within a home, and, yes, often water from a bathroom tap is colder than water drawn in the kitchen—which is why we suggest you cool your beer in the bathtub and bathe in the kitchen sink.

To understand this phenomenon, assume for the moment that your home is supplied by city water mains, which, insulated by virtue of the fact that they are underground, keep water pretty cold—around 55 degrees Fahrenheit. Now consider the placement of the various taps in your home. Bathrooms, as the chief dispensers and consumers of water, tend to be located, by design, closest to where the water enters your home to cut down on costly interior plumbing. In short, a bathroom gets its water sooner, which means it's colder when it gets there, and it uses lots of water, which means the water doesn't sit around warming up in your home's toasty 70-degree pipes before it's used. A kitchen, meanwhile, is likely to be situated farther away—so water has more of a chance to warm up on its journey to your tap—and generally uses less water, which means that when you turn on the

tap you're often getting water that's been hanging around indoors for a while. Note: If you draw your water from a well, or your pipes run through concrete slabs, none of this may hold true, so grab a nice cool drink from the toilet tank or the dishwasher inlet hose as the mood may strike you. It won't matter either way.

How did Apple settle on nine minutes as the snooze time for its alarm clock?

When you're Steve Jobs, you only need nine minutes, baby. That's how good he was. In nine minutes Jobs could redesign the iMac, invent 16 new, never-before-seen-on-earth colors for your kid's iPod Touch, and dash off a complete schematic for the upcoming iToaster Air, which somehow would actually be thinner than a single slice of bread.

In truth, the nine-minute standard is one thing Apple didn't invent. It traces its roots to the very first snooze button, introduced by a General Electric subsidiary called Telechron in 1956. Basically they added a switch hooked up to the existing gears in the clock, which, due to the way they happened to mesh, made a more-intuitive-feeling, round-numbered ten-minute extension impossible. So nine minutes it was, and it just kind of stuck—a nostalgic nod to analog quaintness in a shiny, precise digital age.



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To some, sunglasses are a fashion accessory...

But When Driving, These Sunglasses May Save Your Life!

Drivers' Alert: Driving can expose you to more dangerous glare than any sunny day at the beach can... do you know how to protect yourself?

The sun rises and sets at peak travel periods, during the early morning and afternoon rush hours and many drivers find themselves temporarily blinded while driving directly into the glare of the sun. Deadly accidents are regularly caused by such blinding glare with danger arising from reflected light off another vehicle, the pavement, or even from waxed and oily windshields that can make matters worse. Early morning dew can exacerbate this situation. Yet, motorists struggle on despite being blinded by the sun's glare that can cause countless accidents every year.

Sometimes it does take a rocket scientist. A NASA rocket scientist.

Some ordinary sunglasses can obscure your vision by exposing your eyes to harmful UV rays, blue light, and reflective glare. They can also darken useful vision-enhancing light. But now, independent research conducted by scientists from NASA's Jet Propulsion Laboratory has brought forth ground-breaking technology to help protect human eyesight from the harmful effects of solar radiation light. This superior lens technology was first discovered when NASA scientists looked to nature for a means to superior eye protection—specifically, by studying the eyes of eagles, known for their extreme visual acuity. This discovery resulted in what is now known as Eagle Eyes®.

The Only Sunglass Technology Certified by the Space Foundation for UV and Blue-Light Eye Protection. Eagle Eyes® features the most advanced eye protection technology ever created. The TriLenium® Lens Technology offers triple-filter polarization to block 99.9% UVA and UVB—plus the added benefit of blue-light eye protection. Eagle Eyes® is the only optic technology that has earned official recognition from the Space Certification Program for this remarkable technology. Now, that's proven science-based protection.



Slip on a pair of Eagle Eyes® and everything instantly appears more vivid and sharp. You'll immediately notice that your eyes are more comfortable and relaxed and you'll feel no need to squint. The scientifically designed sunglasses are not just fashion accessories—they are necessary to protect your eyes from those harmful rays produced by the sun during peak driving times.



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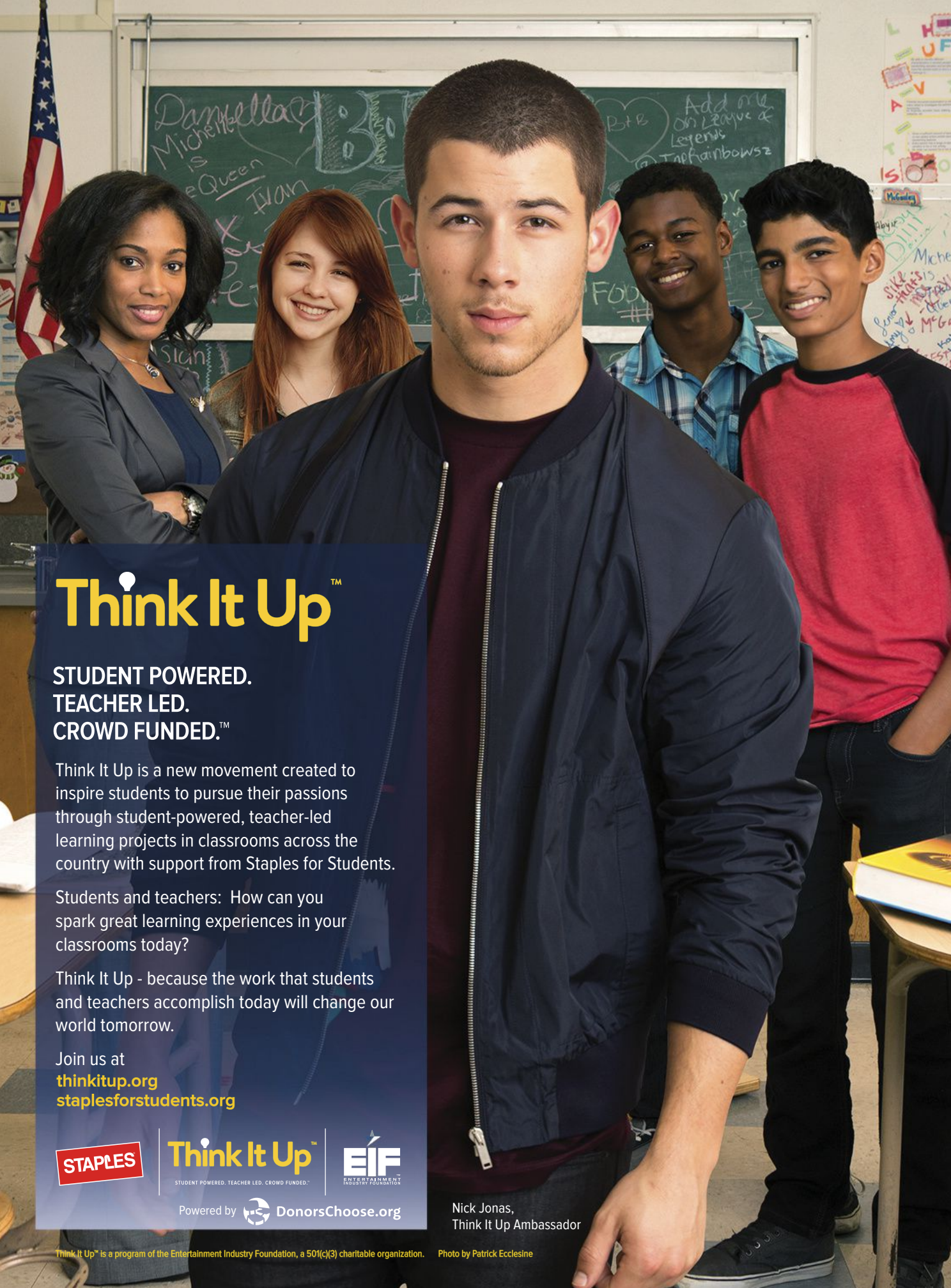
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Think It Up Ambassador

SKILLS



BLUE CRAB: A USER'S MANUAL

Choosing, cleaning, and cooking your own crab is as important a skill as building a fire or running an electrical outlet. Plus, it leads to dinner. If you want crab that is sweet and briny and tastes different from any other crab in the world, you want Maryland blue crab. And you want them from only one place: the Chesapeake Bay.

BY FRANCINE MAROUKIAN

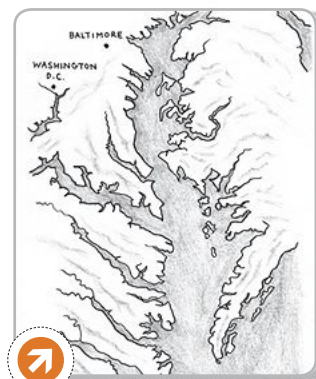
THE SOURCE

The Chesapeake Bay is the country's largest estuary, a dynamic mix of freshwater and seawater running along the Atlantic from Havre de Grace, Maryland, to Norfolk, Virginia. Responsible for creating more organic matter than comparable-size areas of agricultural land, the Chesapeake is a massively productive wetlands ecosystem supporting

more than 3,600 species of plants and animals, including its iconic resident, the Maryland blue crab, which also happens to be a key indicator of the bay's overall health.

In its natural, unpolluted state, the Chesapeake's brackish water provides ideal conditions for the crab. Heavy, salty water from the ocean end of the bay slides under the lighter, fresher

water that flows in from the Susquehanna River in the north, giving the crab its distinctive blend of salinity and minerality. Since the bay is relatively shallow, the sun can easily penetrate to the vegetation below the surface, providing the crabs with a good foraging habitat and delivering plenty of oxygen through photosynthesis. Plus, there are the oysters, which ▶



Male crab are found along the entire perimeter of the bay. Females tend to cluster in the higher salinity water in the south, preferring it for spawning.

The Chesapeake is a massively productive wetlands ecosystem supporting more than 3,600 species of plants and animals.

► purify the water. Each adult filters up to 50 gallons a day.

But over the years, environmental disturbances both natural and man-made have turned every crab season into an unknown. “What affects crab abundance is highly debated,” says Spike Gjerde, a 2015 James Beard Best Chef award winner, and the chef and owner of Baltimore’s Woodberry Kitchen. “We start with the annual dredge survey to measure crab density, including juvenile and spawning population, and then as those numbers are projected, use them to implement management practices, like allowable harvesting percentages, for when the crabs start to molt.” In response to the lower counts and rising prices of Chesapeake blue crab, many local tourism-focused “Maryland crab houses” make crab cakes using imported crabmeat from Indonesia and China. Which is just not the same, and which is why you should look for the True Blue logo (below) before sitting down to eat.



STAGES

Two types of crabs are harvested from the Chesapeake, hard-shell and soft-shell (called soft crabs by Marylanders), and they represent different life cycles of the same species: *Callinectes sapidus* (Greek for “beautiful swimmer,” and Latin for “savory”). As the water warms up in late spring, dormant crabs molt their upper hard shell so the soft body has room to grow under a new, larger shell.



HARD

Swimming crabs with a bluish-green upper carapace and ten appendages: three pairs of walking legs, one pair of swimming paddles, and one pair of claws.



PEELER

Premolt crabs, called peelers, typically show a white line on the paddle fins (the new shell), which turn pink and finally red right before the crab begins to back out of the old shell.



SOFT

After the hard shell molts, what’s underneath is the slippery, olive-green soft crab, with thin, spindly legs and a paper-thin exoskeleton that hardens within hours.

→ HOW TO PROPERLY PRONOUNCE BALTIMORE
BAWL-mer

HOW TO SEX A CRAB



There are multiple ways to tell a sook [female] from a jimmy [male]. Sooks have red-tipped claws like painted fingernails, and jimmies have brilliant blue claws. Or you can flip them over and look at the belly, or apron, for these indicators:

THE U.S. CAPITOL



Female

THE WASHINGTON MONUMENT



Male



Started in 2012 by the Maryland Department of Natural Resources (and Spike Gjerde), the True Blue initiative is a state certification process that authenticates the use of genuine Maryland crab in restaurants. Find participating locations at the program’s succinct and easy-to-remember website: seafood.maryland.gov/true-blue-maryland-crab-meat.

PREPARATION AND CONSUMPTION

BY SPIKE GJERDE

SOFT CRABS

1. BUY

- ▶ Soft-shells must be active. When lifted, crabs should still move a bit rather than limply hang.
- ▶ Buy the softest crab you can find. (You're eating the shell, after all.) To test, don't press down on the center surface. That's where the gills are located, and too much pressure can crush them, killing the crab. Instead, gently pinch the tips of the claws. If they're still soft, that's perfect.
- ▶ Cook crabs on the same day they are cleaned.

2. CLEAN

You can clean them yourself, but it is more efficient and less traumatic to let the fishmonger do it for you. What he'll do:

- Snip off the eye side with a scissor.
- Lift up each side of the soft shell and remove the gills.
- Turn the crab over to remove its apron, the hinge-like tab that resembles a zip top on a beer can.

3. COOK

Sautéed Soft Crabs

Use 10-inch skillet over medium heat.

Coat **2 cleaned soft crabs** with spiced flour (**1 cup all-purpose flour** mixed with **1 Tbsp cornstarch** and a **pinch** each **piment d'Espelette**,* **ground black pepper**, **coarse salt**), shaking off excess. Reserve on rack. Melt **3 Tbsp unsalted butter** until foaming, then add crabs, top side down, until golden brown, about 3 or 4 minutes. Carefully turn and brown the other side, about 2 or 3 minutes. Drain briefly on paper towel to remove excess butter.

*A dried red pepper from the seafaring Basque coast of France. It's available in most grocery stores.



HARD-SHELL CRABS

1. BUY

- ▶ The best crabs are feisty and can actually bite, so touch at your own risk.
- ▶ To get the crab with the most meat, consider weight *and* size. When a crab molts its old shell, the new shell can be much larger than the actual crab body underneath. Get the fishmonger to weigh them, or grab the crab by the back fin to get a feel for its density.



2. COOK

Steamed Crabs

Serves 8. Use a large crab steamer with insert or 12-quart stockpot over high heat.

(Submerging Maryland crabs in boiling water drowns their natural sweetness. Instead, steam them over intense heat using less liquid.)

Bring to a boil **2 bottles beer** (something light, like National Bohemian), **24 oz water**, and **8 oz apple cider vinegar**. Layer in **4 dozen Maryland blue crabs**, sprinkling **crab seasoning*** generously over each layer. (Use about 1 cup total.) Cover, and once steam rattles the cover and leaks out the sides, cook for 20 minutes. Drain. Transfer to a newspaper-covered table. Arm yourself with a mallet and paring knife (preferably dull).

*½ cup sea salt, 3 Tbsp whole black peppercorns, 1 Tbsp ground piment d'Espelette, 2 tsp mustard seed, 2 Tbsp dried lovage. Grind all together using an herb or coffee grinder, or in a small food processor. Or use Old Bay, a distinctive spice mix for cooking crustaceans, originally produced in Baltimore in 1939.

3. EAT

Fig. 1



Fig. 2



Fig. 3



Fig. 4



Fig. 5



- ▶ Twist and break off the two large front claws (fig. 1). Set aside.
- ▶ Flip the crab over and pry off the apron with the knife (fig. 2). Flip again and use the back of the blade to break off the top shell.
- ▶ Pull out the spongy gray gills, called dead man's fingers, and scrape out the mustard-yellow intestines. Holding the crab firmly in both hands, snap the body in half (fig. 3).
- ▶ Twist off each back fin, reserving that meat to eat, and use the knife to dislodge the meat lumps inside the shell (fig. 4).
- ▶ Get the meat out of the reserved claws by holding the tip of the knife blade near the pincer and tapping the back of the blade with the mallet (fig. 5). Do both sides. The shell will split open and expose the meat in one piece. (Resist the temptation to crack the claw with the mallet. It will smash the shell, but it will also pulverize the meat.)

THE TOOLS



KNIFE Gjerde likes the Rada Cutlery regular paring knife (\$6.50). It has an aluminum handle instead of wood, which means it doesn't get slimy, and it's dishwasher safe.



MALLET Buy crab mallets where you buy crab. They're cheap—a buck and a half—and superlight, meant not to pulverize the shell but to gently tap the knife through it.



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MITER SAWS LOSE THEIR CORDS

Increased portability doesn't have to mean decreased performance.

BY JOSEPH TRUINI
and ROY BERENDSOHN



MAKITA XSL01Z LXT \$759

★★★★★

▲
VOLTAGE/
AMP-HOURS:
18-v/5-Ah

Crosscut capacity: 12¹/₁₆ in.

1 x 4 cuts per charge: 356

Likes: The Makita's low-speed, high-torque motor is extremely powerful. It pairs perfectly with the saw's 40-tooth blade and slide action. Between the motor and the saw's crosscut ability, you have a machine that can slice huge crown molding or framing lumber.

Dislikes: A great saw, but it's expensive. The one we tested had the optional 5-Ah battery, which costs an additional \$219. All but the most demanding users will be fine using the standard 3-Ah batteries.



DEWALT DCS361 \$400

★★★★★

▲
VOLTAGE/
AMP-HOURS:
20-v/4-Ah

Crosscut capacity: 8³/₁₆ in.

1 x 4 cuts per charge: 249

Likes: This is a fine product for professionals or advanced hobbyists who can afford the premium for something industrial-grade. The DeWalt has power to spare and makes a cut that's nearly mirror-smooth. It operates flawlessly with dead-on accuracy. And it's built like a tank.

Dislikes: It's not exactly a big deal, but we expected it to make more cuts per charge.



CRAFTSMAN BT2010 \$160

★★★★

▲
VOLTAGE/
AMP-HOURS:
19.2-v/4-Ah

Crosscut capacity: 4⁹/₁₆ in.

1 x 4 cuts per charge: 272

Likes: The Craftsman and Ryobi are twins separated at birth. Almost everything said about one applies to the other. This is a lightweight, fast-cutting saw with excellent fit and finish and a small footprint.

Dislikes: We're nitpicking, but the indented area that holds the table insert could use a beveled edge to keep wood from catching on it.



RYOBI P551 \$130

★★★★

▲
VOLTAGE/
AMP-HOURS:
18-v/4-Ah

Crosscut capacity: 4⁹/₁₆ in.

1 x 4 cuts per charge: 300

Likes: As with the Craftsman, a good, fast-cutting saw with excellent quality of construction. It's handy, lightweight, and has a small footprint. The main difference is that Ryobi throws in an adjustable laser line to better align your cuts.

Dislikes: Like the Craftsman, it would also benefit from a beveled edge on the table insert.

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With Wi-Fi and a ten-dollar subscription, anyone can have access to millions of songs. Instantly. The sheer volume can be overwhelming, but not if you know where—and how—to look. We tested out the best and newest ways to find your new favorite band, no matter what type of music fan you are.

BY ALEXANDER GEORGE



Obsessed with new music

YOU LIKE: Anything by a former member of Odd Future



TRY:



► Before they are released on major music services, songs have to go through legal processing. In the meantime many artists publish them here. Find bands you like, and listen to the bands they follow. That's how we found South African producer Nozinja, who led us to R&B singer Kehlahni. **App and website.**

Pressed for time and looking for human recommendations

YOU LIKE: Bruno Mars and, although you wish it weren't the case, Hozier



TRY:



► Head to the Brand New Music section at Songza to stream the tracks that the site's experts cull from all the music blogs you don't have time to visit. Like Apple Music's radio stations, Google Play Music subscribers can save the songs for offline listening. **App and website.**

Encyclopedic in your musical knowledge, or bored at work

YOU LIKE: Sharon Jones and the Dap-Kings, Gorillaz



TRY:



► Users post songs to Reddit's Listen to This page, and readers vote them up or down. The site automatically removes mainstream artists, so it's almost guaranteed to be stuff you've never heard. One find was a startlingly bawdy 1935 blues tune called "Shave 'Em Dry." **Website.**

An indie fan, possibly an original Pitchfork reader

YOU LIKE: Sufjan Stevens



TRY:



► Music-obsessive Clark Dinnison scours the Web for new tracks and publishes a weekly playlist on his app, Noon Pacific, all for free. The artists are almost always unknown, and the tracks are reliably great. **App and website.**

A fan of live music, preferably performed by singer/songwriters

YOU LIKE: John Prine, Greg Brown



TRY:



► This nonprofit collects public radio recording sessions from around the country. Find obscure live sets from your favorite group, or all-new artists from the suggestions automatically placed in your queue based on what you listen to. (Tip: Starting with Houndmouth did right by us.) **App and website.**

Set in a routine, both musically and in life

YOU LIKE: Talk radio at breakfast and mellow jazz before bed



TRY:



► Push the center button and, based on time of day and your listening habits, Aether Cone plays a podcast or song it finds appropriate. Rotate the circle around the speaker to skip tracks and change genres. At \$399 it's an expensive way to listen, but it delivered more surprises than the other options. **Speaker.**

In a musical rut, unsure of where to start

YOU LIKE: Wilco, Arcade Fire **TRY:** AN ACTUAL RECORD STORE

► Having a live person spend a few minutes getting to know you and your tastes, then tell you, with conviction, that you'll really dig these Nigerian female vocalists' 1976 album is an experience that no website can match. That album, by the way, is *Danger*, by the Lijadu Sisters. Thank you, bearded guy at Other Music in Manhattan.





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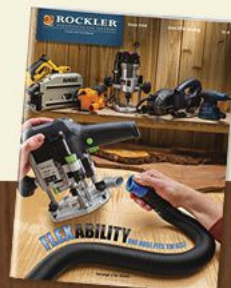


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DISASSEMBLY REPORT:

OUTBOARD MOTOR

MODEL: MERCURY MARINE 6HP

NUMBER OF PARTS:	PRODUCED:
501	KOMAGANE, JAPAN
	TIME TO DISASSEMBLE:
	9 HOURS, 20 MINUTES

NOTES: Outboard motors can be big, bolt-in-place monsters that produce more power than a sports car or, like this 57-pound Mercury Marine 6HP model, smaller clamp-on powerplants with just enough juice to troll for walleye on a nice afternoon.

- 1
- CYLINDER HEAD:** As in your car, the cylinder head is where the spark plug plugs in. But this cylinder head also houses a thermostat. When the engine reaches a high enough temperature, the thermostat opens so cold water can enter and cool the motor.
- 2
- CAMSHAFT:** Operates the motor's valve system. As the camshaft turns, its cams push against rods (called pushrods, see?) that open valves on the cylinder to let fuel in and exhaust out.
- 3
- WATER-PUMP HOUSING:** The motor is cooled by water from around the boat, which is pumped along the driveshaft. The driveshaft also powers the water pump, so as the engine revs up, more water is pumped in.
- 4
- DRIVESHAFT:** The length of the driveshaft you need is determined by the height of the transom on your boat. (Engines are much

- 5
- more effective when the propeller can reach the water.)

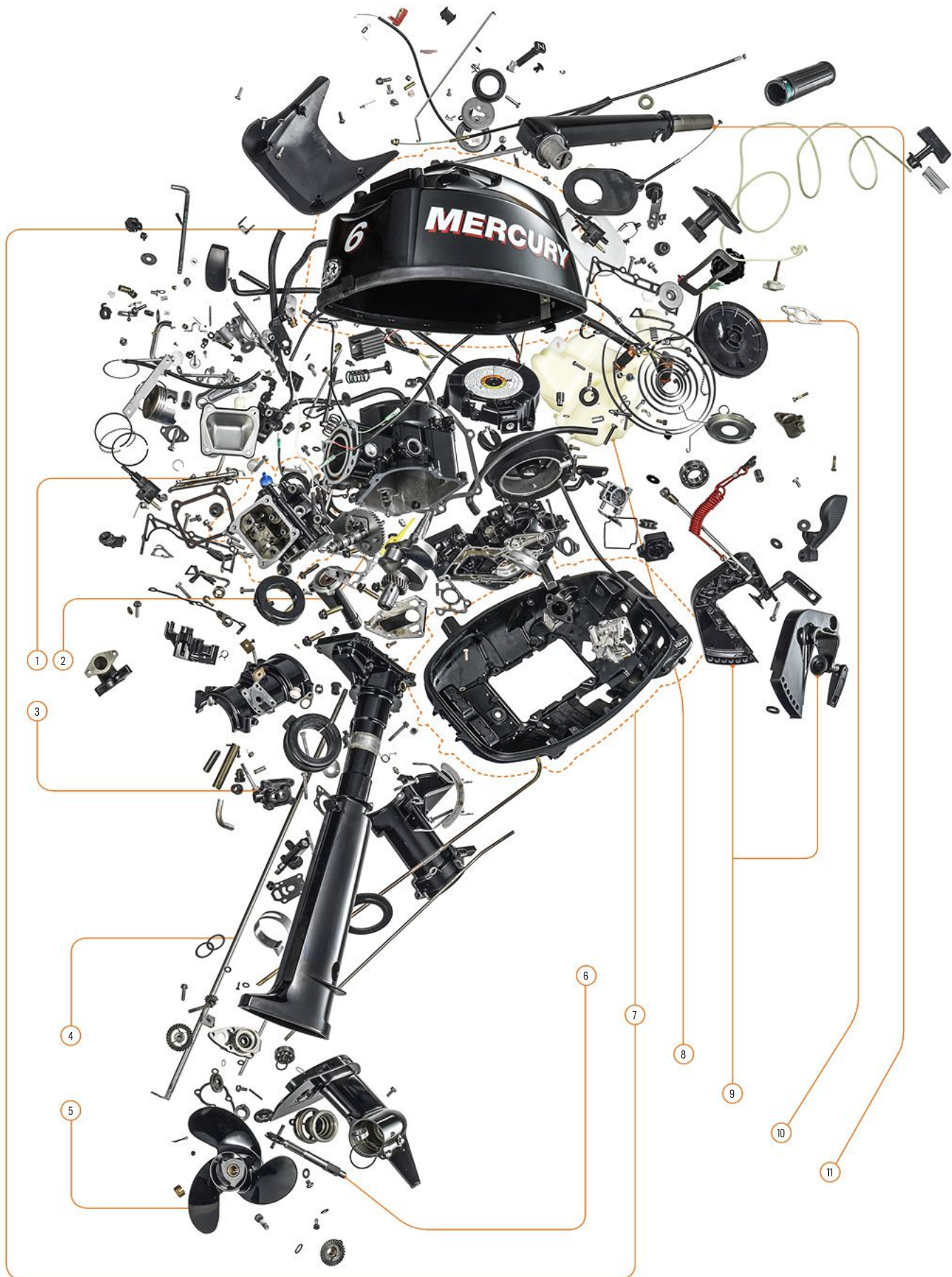
PROPELLER: A propeller is essentially a set of wings that rotate. The shape of an airplane's wing generates lift by manipulating air pressure. Similarly, a propeller's shape generates thrust by manipulating water pressure: Acceleration is caused by an absence of pressure behind the blade. Water rushes in to equalize the pressure, propelling the boat forward. Also, if you want to fit in on the docks (or at least in the service areas), refer to the propeller as a screw.
- 6
- PROPELLER SHAFT:** This transfers the power created by the driveshaft to the propeller. A clutch slides along the propeller shaft, linking it to either the forward or reverse gear. As the shaft turns, it turns the propeller in the same direction.
- 7
- COWLING:** The cowling contains the motor and includes a carrying

- 8
- handle, since a motor this size can be easily carried around.

FUEL TANK: Holds enough gas to run the motor at full throttle for one hour. If that isn't enough for your plans, the motor is pre-plumbed for adding an external fuel tank.
- 9
- CLAMP BRACKETS:** These attach the motor to the boat and adjust the trim—the angle between the propeller and the water. If the motor is trimmed out so that the propeller is farther from the back of the boat, you get a higher top speed. Tuck it in toward the boat for faster acceleration.
- 10
- FLYWHEEL:** A four-stroke engine like this one delivers power on the third stroke. (The piston lowers on the intake stroke, compresses an air-and-fuel mixture on the second stroke, gathers power after the fuel is ignited on the third stroke, and pushes out exhaust on the fourth stroke.) But something has to help it get started. When you yank the starting cord, the flywheel rotates and its momentum helps the engine turn over (or run through the first few movements). If the motor is in gear, a little nub called a pawl blocks the flywheel from spinning so that you can start only in neutral.
- 11
- TILLER HANDLE:** Move the handle toward the port (left) side of the boat to steer to the starboard (right) and toward the starboard side to head to port. The grip operates the throttle. Two cables link it to the carburetor. A twist controls how much fuel goes to the engine.

—KEVIN DUPZYK

HOW MUCH HORSEPOWER DO YOU NEED TO . . .	
Fish	0
Troll for fish	6
Run a pontoon boat	35
Pull a kid on an inner tube	60
Pull an adult on water skis	115
Pull a portly adult on water skis	150
Power your yacht	1,500



Popular Mechanics' senior home editor solves your most pressing problems.

BY ROY BERENDSOHN



Our kids smashed an insulated-glass window playing baseball. The outside pane is broken, and the inside pane has a small crack. Can we replace just the insulated glass, or do we need to get a new window?

HARRIET F., KANSAS CITY, MISSOURI

A Unlike single-pane windows, which secure glass with an easily replaceable putty, double-paned windows are more complicated. You shouldn't try repairing them yourself. John Waslenko, owner of Thornridge Hardware Supply in Levittown, Pennsylvania, says that you can easily damage the sash trying to fix the glass. Once that happens, there's nothing he can do. You'll need a new window.

The good news is that removing the sash and bringing it in for repair is relatively easy. Most double-hung windows tilt out. Undo the thumb latches and tilt the sash into the clean position. Tip one of the free corners down while lifting the opposite corner (the one still in the window frame) up. Some

wood-insulated windows lift out in a similar way, while others require a screwdriver to unsnap a clip between the jamb and the sash.

The shop will remove the stops that hold the insulated glass. If the window is wood, the stops are usually thin wood strips held with brads driven into the sash. If the window is vinyl, the stops will be vinyl strips with a lip that fits into a groove in the sash. If you have wood windows that are more than 20 years old, they often have no stops. The insulated glass is held in place by the sash itself, which is nailed together. With these windows, the shop has to dig out the putty over the nailhead, remove the nail, and disassemble the sash. Next, the shop will cut away the caulk the insulated glass is embed-

ded in. Finally, it will take the new insulated-glass unit, embed it in new caulk, and reassemble the window. This job can take as little as a few hours to a couple days, depending on the parts that need to be ordered.

Q We painted our house last year, and I recently noticed a big water-filled blister on the side of it. What did we do wrong?

EVAN B., YAKIMA, WASHINGTON

A The problem isn't the paint but moisture. It can come from a roof leak, a plumbing leak, an unvented and heavily used bathroom, or a small, poorly ventilated kitchen. As the sun beats down on the house, excess moisture caused by any of these issues seeps through the wall to the outside. When you had your old paint, much of its damage was probably caused by this moisture. The paint became so porous that water vapor could pass right through. A couple coats of new paint, however, can trap this vapor and form a blister. When the vapor cools, it condenses into water and remains inside the bubble. To solve the problem, you need to find the source of the moisture, then fix it by adding ventilation or sealing the leak.

Q My two-story garage is built on a steep hill. The back gutter gets clogged with pine needles, and it's too high for me to clean easily or safely. Can I just remove the gutter?

DAVE S., FORT MILL, SOUTH CAROLINA

A Gutters are very useful. They handle roof runoff in an orderly manner, preventing excessive splash-back against siding, and soil erosion and soggy conditions next to the foundation. I don't think you'd experience the soggy conditions, because the water runs downhill, but you would see splash-back and erosion from the impact of the runoff falling two stories. Instead of removing the gutter, try Gutter Helmet, an attractive metal cover that blocks debris yet allows runoff to flow freely into the gutter.



IS POWER THE SAME AS ELECTRICITY?

Nope. Electricity is a type of energy, just like wind or solar, and it's measured in amps and volts. Power is the rate at which energy is transferred, measured in watts (joules/sec). For example, an engine is powerful if it quickly converts chemical energy in fuel to mechanical energy. When the TV suddenly cuts off, it's because the electricity went out, not the power. Either that or your wife has the remote and is gently reminding you to get to work on the basement, like you promised.

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CARS



With only a souped-up golf-cart engine, the Strati prototype can hit a top speed of more than 30 mph.

HOW TO MAKE ANYTHING

HOW TO MAKE A CAR . . . IN TWO DAYS

The Local Motors Strati roadster is the world's first 3D-printed vehicle. Somewhat surprisingly, it's also a blast to drive.

This spring Fiat Chrysler CEO Sergio Marchionne called out the auto industry for the staggering amount of money it wastes in the design and manufacture of cars. His solution is based on classic business principles: consolidate and eliminate redundancy. Local Motors CEO Jay Rogers perceives the same challenge, but he's attacking it from a completely different direction. For Rogers, the problem stems not from business organization but from the fact that we still build cars the same way we did in 1915, on assembly lines with thousands of individual parts. It doesn't have to be that way, and the proof is parked in his Knoxville, Tennessee, garage, charged up and ready for a drive.

Local's answer to the cost-cutting question is the Strati, the first 3D-printed car. It's a humble (albeit very cool-looking) thing. Built—printed—in Detroit, in collaboration with Oak Ridge National Laboratory in Tennessee, the Strati is a small electric two-seater, the first of many models in Local's plans. Two factories, scaled to employ 100 people each, are under construction now and scheduled for completion by the end of the year. Local plans to build its own cars, but it could also end up working as a supplier for original-equipment manufacturers, some of whom have met with Rogers already. "One of them said, 'This would



be great for prototyping,” Rogers says. “And I said, ‘Forget prototyping! This is how you make the car.’” That’s the radical big idea, the one that prompted *Popular Mechanics* to bestow a Breakthrough Award on Local Motors last year.

The world’s first 3D-printed car is crude by design, its dashboard looking like stacked silicone beads from a caulking gun. Its flanks, meanwhile, are smooth, resembling the exposed parts of the BMW i3’s matte carbon tub. “We milled the sides to show how that would look,” Rogers says. “Some of the other parts are just how they came out of the printer, so you can see that. But we can make it look however we want. You could put a vinyl wrap on it and the car would still be completely recyclable.”

The Strati is printed from carbon-fiber-reinforced plastic, a versatile, strong, and relatively cheap material that could enable some new approaches to safety. Thanks to the nature of 3D printing, where the car is built in layers squirted from the nozzles of a massive printer, you can embed energy-absorbing crash structures or superstrong seat-belt mounts that are anchored deep in the body. You could bond springy bumpers to cushion pedestrian impacts (right now Local is experimenting with a printable elastic polyurethane material called NinjaFlex). And if you managed to catastrophically damage the tub, you could unbolt the motor and suspension, melt the car down, and print a new one. Of course, the Strati parked in Knoxville doesn’t even have seat belts, but it’s proof of concept.

The prototype I drove is the third that Local has printed and took about 40 hours. The company is currently looking for an electric-powertrain supplier, so for now the Strati has a beefy golf-cart motor as a stand-in. The rear-wheel-drive Strati is envisioned as a city car, but Rogers isn’t blind to the performance possibilities. “If you put a motor with 150 or 200 horsepower in here, it would be a lot of fun,” he says.

It’s a lot of fun already. The rear suspension rides on an aluminum subframe,

Clockwise from right:
Because it’s so light, the Strati’s steering is unassisted; the fenders are printed separately so that a fender bender won’t require reprinting the entire vehicle; the wheels are large-diameter but super-narrow to accommodate high-pressure, low-rolling-resistance tires.



and with no distinction between body and chassis, the car feels inordinately solid, substantial. There’s some clunking from the stand-in motor, but the car itself is silent. Put a Mitsubishi i-MiEV motor back there and this thing would be a riot.

The last car I tested with a one-piece carbon tub was a McLaren 650S that cost more than \$300,000. This Strati, lack-luster motor notwithstanding, could cost about \$5,000. No, it’s not a McLaren. But to the family of five that crams aboard a motorcycle to get around—Rogers recently witnessed exactly that on a trip to India—it might as well be.

Developing countries would love this

technology for cheap transportation, but so might the rich guy who wants a thousand-horsepower car of his own design, printed in a production run of one. Or the carmaker that wants to churn out a complete car in ten hours rather than 24, using a fraction of the components. Modern cars are complicated, but the union of 3D printing and electric propulsion—where the motor has just one moving part—points to a future in which that’s no longer a given.

We currently take it for granted that cars are complicated and expensive. When you’re driving the Strati, it’s easy to imagine a day when we take it for granted that they’re not.

IN PRAISE OF

THE BORROWED ENGINE

Starring the 2005 Morgan Aero 8.



I recently drove a 2005 Morgan Aero 8, a car that combines traditional Morgan funkiness (components made out of wood, unsymmetrical aluminum bodywork) and a BMW V-8. And, I’ve got to say, what an outstanding combination: the visceral reactions of a handmade British roadster paired to big, reliable V-8

power booming out of side pipes just below the door.

This kind of thing—car companies borrowing one another’s engines—used to happen all the time. The previous-generation Range Rover used V-8s from BMW and Ford, and the Saturn Vue once ran a Honda V-6, for reasons that were never

entirely clear. These cross-pollinations resulted in some strange but fun alchemy. Factory-sanctioned motor swaps aren’t as popular these days, but there are a few worthy freaks out there. Run a Scion FR-S through the gears and it’ll sound like a Subaru. Because under the hood, that’s what it is.



The F-Type's electronic active differential works in conjunction with its AWD system for maximum traction.

"The taller the tire, the longer the contact patch, and the better the longitudinal traction to put the power down and accelerate. Compounds and internal materials have come a long way. We now have super-high-strength steel belts that are more flexible, so the tire can conform to the shape of the ground. With the Z06, I think you're getting the maximum possible acceleration for a front-engine, rear-wheel-drive car."

SOLUTION 3

GO MIDENGINE

Every car in McLaren's lineup is a beast, with the least powerful model cranking out 570 horsepower. Not coincidentally, every McLaren has its engine mounted behind the passenger compartment, moving the weight distribution rearward, closer to the drive axle. That's a boon from an acceleration standpoint, but there's a cascade effect of benefits. "It's about straight-line traction, getting the power down, but it's also about cornering," says Dan Parry-Williams, McLaren's chief designer. "With the weight concentrated around the middle of the car, you make it very nimble." You also reduce overall mass (and, subsequently, inertia), since the engine is closer to the transmission and to the rear-driven wheels, quickening response time. Meanwhile the driver is up front, closer to the front tires, shortening steering inputs. "You can get a good weight distribution in a front-engine car," Parry-Williams says. "But you might have a long propshaft, with the driver seated farther rearward and outboard." So the future isn't solely about deploying 650 horsepower in the most efficient way possible. It's about doing it with style.

THE HORSEPOWER PROBLEM

As cars get cartoonishly more powerful, maintaining traction is the newest engineering hurdle for automakers.

Seven hundred horsepower is the new 500 horsepower, and every performance car worth its carbon-fiber diffuser is packing either a supercharger or a turbo. Traction problems were once confined to the launch—once you were rolling, you could hammer down. The new reality is epitomized by the Dodge Hellcats and the BMW M5, cars that could lay rubber all the way down the quarter-mile if you please. With horsepower numbers heading ever higher (who'll be first to 800?), finding a way to deploy all that energy is becoming the paramount challenge for chassis engineers. Here are three approaches to keeping big power from going up in smoke.

SOLUTION 1

ALL-WHEEL DRIVE

For 2016 Jaguar endowed all V-8-powered F-Types with all-wheel drive, thus solving any traction problems that might have afflicted the newly upgraded 550-hp F-Type R coupe. On a test drive at Monticello it powered through and out of corners at borderline-three-digit speeds without the slightest complaint. "There's a limit to the acceleration you can achieve with front-engine, rear-drive," says Tim Clark, Jaguar's chief technical specialist for powertrains. "Somewhere between 8 and 8.5 meters per second squared—a little

less than a g—is about your limit. Now with all-wheel drive we can reach 10 meters per second squared and above. You can access more of the performance more of the time in more conditions."

SOLUTION 2

BETTER TIRES

What would happen if you mounted a state-of-the-art performance tire from ten years ago on the 650-hp 2015 Corvette Z06? "The Z06 would fry that tire," says Oscar Pereda, a former engineer who's now director of marketing for Michelin ultra-high-performance tires. Over the past decade performance tires have changed significantly in terms of construction, compounds, and even in the basic matter of size. "The overall diameter's been going up dramatically," Pereda says.



The manufacturing process for Corvette's tires is kept top secret.



A midmounted motor puts weight on the driven tires.



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2015 GMC YUKON XL DENALI

→ With most trucks, a fancy trim level—Platinum, Double-Platinum, Donner Pass Desperado—buys you some nice leather and a few badges. In the case of the GMC Yukon, the Denali trim actually means something, bringing a huge powertrain upgrade (and also nice leather and badges).

Standard Yukons have a 5.3-liter V-8 and a six-speed transmission, but Denalis get a **420-hp 6.2-liter** and an **eight-speed transmission**. The added power is welcome in a vehicle that, in XL trim, weighs as much as 6,000 pounds. With its long wheelbase and **460 pound-feet of torque**, the Denali is a great tow vehicle. But the waist-high rear-floor height (a function of the solid axle underneath) reminds you that this isn't a minivan or even a crossover. It's a truck, and it feels like one. So with the third row folded, the cargo area is so deep that you'd need some kind of fireman bucket brigade to retrieve your groceries from the far reaches.

It's also quite nice inside. The Yukon is new for 2015, and the interior got a lot of help. The inlaid doors and active noise cancellation make for a quiet ride. You could fool yourself into thinking this is an Escalade, and it's close enough as makes no difference. In the words of *Eastbound & Down* antihero Kenny Powers, "If you need me, I'll be cruising in my Escal—my Denali."

2015 BUICK REGAL GS AWD

→ The Buick Regal is an interesting social case study, because it seems to attract the type of driver whom I'd charitably call the aggressive type. Over the past couple of years, I've noticed every time someone in a Regal cut me off or tailgated. And each time I've witnessed a nakedly belligerent maneuver, I've felt a little burst of optimism on Buick's behalf: There goes someone who could've bought an Audi.

The Regal GS, as the sportiest model, is the most likely to attract the kind of buyer who's cross-shopping foreign sport sedans. The **2.0-liter turbocharged four-cylinder** makes **259 horsepower**, and front-wheel-drive models are available with a manual transmission. The GS AWD is available only with an automatic, but it shifts like it means it, particularly when you push the dash button marked GS. That mode firms up the suspension and increases steering effort. The GS has Brembo brakes, by which I mean it has Brembo front brakes, by which I mean it has Brembo front calipers. Hey, people buy cars for all sorts of reasons, and that Brembo logo's worth it, if only to send the message that this car is on a different mission than are other Buicks. If a GS storms up behind you and then blows past on full boost at the first opportunity, you can be mad. But don't be surprised.

2015 JEEP RENEGADE TRAILHAWK

→ Jeep is America's Porsche: a company with one iconic product that everyone loves. And just as every new Porsche inevitably references the 911, every Jeep wants you to know that it's related to the Wrangler. So it is with the Renegade Trailhawk, a small crossover built in Italy. Accessorized like a junior Wrangler Rubicon, complete with skidplates and red tow hooks, the Renegade is a surprisingly competent little 4x4. In terms of off-road ability, it reminded me that it's not all about brute strength, as healthy ground clearance (8.7 inches) and tidy overhangs can sometimes help your cause more than a set of Super Swampers.

On the road you do pay a price for the Trailhawk's off-highway abilities. That's mainly because Jeep offers the Trailhawk with the **2.4-liter four-cylinder** paired only to the ZF **nine-speed automatic**. Lesser models are available with a turbocharged 1.4-liter and a six-speed manual, which is a lot more fun. But the ZF nine's first gear is low enough to enable a **20:1 crawl ratio**, standing in for true low range.

On paper the Renegade Trailhawk is a restyled Fiat. On the road and in the woods, with the dual roof panels removed, it's something else entirely. The Renegade's not a Wrangler, but it's a worthy Jeep.

THE FIVE-WORD REVIEW



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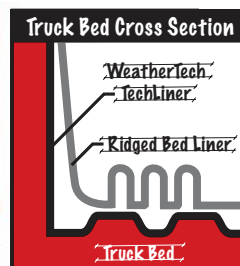
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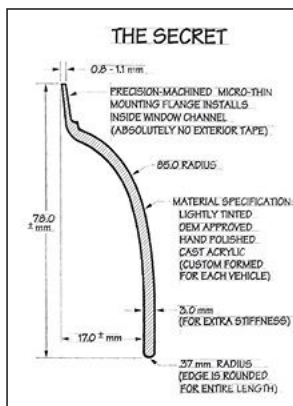
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People say kids don't care about cars anymore.

These people have never been to Freedom High School in Freedom, Wisconsin. Because here they have an auto club.

A really fantastic auto club. And for the kids who spend their free time after school learning how to swap brakes and weld metal, it is their life.





Freedom High's automotive instructor, Jay Abitz (kneeling), and his father, Bob Abitz (second from left), who started Freedom's automotive program, with this year's club and its two project cars.



IF YOU WANT TO BREAK THE ICE with a bunch of high school kids, a Nissan GT-R Nismo is a good way to go. Two minutes after I roll into the parking lot at Freedom High (about a half hour from Green Bay, Wisconsin), a tall, ruddy kid named Cole Woods walks up to introduce himself, his eyes on the car. The Nismo isn't completely out of context, since this is the Freedom

Auto Club's annual end-of-the-year car show, an event where the kids showcase their projects and the local horsepower fiends show up en masse to clear the carbon out of whatever high-strung machinery's been slumbering in the garage over the long Wisconsin winter. Adjacent to the low, brick high school is a lot filled with Chevelles and Mustangs, circle-track race cars, and rat rods. Here a \$151,000 Japanese hypercar raises some eyebrows. I figured a little Nismo show-and-tell would be a worthy way to salute the auto club, which we've been following in these pages for the past eight months as they've restored two of the cars on display here today—Woods's leviathan Oldsmobile and automotive instructor Jay Abitz's 1981 Camaro Z/28.

Abitz founded the auto club in 2009 after realizing that he effectively ran an after-school extracurricular program fixing up cars. "I always had these kids working on their cars after school or at lunch, and I thought we should give this a name and make it official," Abitz says. The program's been a major success, with students learning skills that either propel them into the automotive business or just render them more mechanically competent citizens of the world. Welding, bodywork, brake jobs—this is all stuff I would've loved to have learned in high school. Freedom High even has its own paint booth, always in demand but even more so now after the coverage from a certain major magazine. "A guy called me and asked if we could paint his classic Porsche," Abitz says. The answer was no. We're not doing Pebble Beach cars here, buddy.

Woods, a junior, shows me over to his uncle's 1974 Oldsmobile Delta 88 convertible, a car that he himself painted in the booth. It must've taken a lot of paint, because this thing is a barge. "For my first time painting a car, I think it turned out wonderful," Woods says. "There are some tiger stripes where I sprayed it too thick, but it's okay. I'm gonna drive it."

Abitz's dad, Bob, got the paint booth installed in 1972, when he began teaching automotive classes at Freedom. Back then there were lots of high schools with

paint booths. Now Freedom's paint shop is an outlier, and not for the usual budgetary reasons that always pertain to school infrastructure. "Nobody around here's painting cars anymore because nobody can teach it," Abitz says. "When the guys from the '70s and '80s retired, nobody stepped up to take their place. It's a strange job, because if you want to go work at a body shop, you don't want to go to college for four or five years to get a teaching degree. And vice versa."

From looking around Freedom High's parking lot on this overcast Saturday morning under the big white water tower that says FREEDOM, 22 days before graduation, you can tell Abitz stepped up, and it's working. Students, parents, toddlers, local enthusiasts, teachers, and neighbors walk up and down the rows of gleaming machines, most of which have their hoods up. Volunteers cook burgers and hot dogs under a tent. Next to that, staff from a nearby technical school recruit potential enrollees. The students in the auto club prepare to judge the cars in various categories, and a table holds a row of wooden plaques to be given out as awards—the students made those too.

One particularly menacing 2011 Camaro at the show belongs to Justin Hendrickson, Freedom High class of '99. The auto club didn't exist when Hendrickson went here, when he was surprising locals with a Geo Prizm that he'd built to run 13-second quarter-miles. "I wish there had been something like the auto club when I was here," he says. "I like to come back and support it however I can." Like maybe by rolling in with a Camaro that hides twin turbos under the V-8's exhaust manifolds. The Nismo is officially not the most powerful machine in this high school parking lot.

The auto club isn't just an echo chamber for like-minded car nuts. It attracts kids who might've been indifferent toward cars until they got their license and realized how profoundly a car can change a person's life. "I wasn't into cars at all until this year," says Ryan Lucier, a skinny kid wrapping up his junior year. "I was into skateboarding, and I thought Freedom was kind of boring. But any place will seem lame if your mom has to drive you around. Getting my license made me more excited to be in Freedom. You're out in the country, but you're not far from cities with lots going on."

If, that is, you have a car. Lucier has a Pontiac Grand Prix with a naturally aspirated 3.8-liter V-6. "I wanted a supercharged one, but my parents wouldn't let me," he says. Probably a good move, parents. Not to disparage young Ryan's driving, but I do notice quite a few stripes of rubber in the ol' Freedom parking lot. And the skid marks are activating some latent hormonal lobe in the brain that makes me want to get into the GT-R and rip some righteous donuts out behind the gym, the way my 17-year-old self certainly would've done if armed with 600 horsepower.



BURN RUBBER. DON'T BREATHE IT.

Being older, wiser, and 12 percent more mature now than I was then, I take the Nismo off-site before I spool up the GT3-sized race turbos. The kids queue up for rides, and I try to remind myself that I'm the responsible adult and should set a good example. But there *may* have been a couple of times, in first-gear situations, when I demonstrated the concept of torque vectoring in a way that *might* have been memorable.

On one ride the shotgun seat is occupied by a serious kid named Cody Walrath, an accomplished wrestler who won first place at the state skills challenge for auto-body repair. He had to fix a dented fender, repair a plastic ▶

From left: Cars arrive at Freedom's biggest car show yet—125 entrants; the club's Camaro Z/28 project car with a final coat of shadow gray and two coats of a flat-satin clear; as a tribute to a former club member who died, this year's club and alumni restored his Camaro, now with 450 horsepower; auto club member Cole Woods leans against his 1974 Oldsmobile Delta 88, which won best student build.

How to Start an Auto Club

Building a car isn't easy. Neither is starting a successful after-school program for teenagers. The founder of the Freedom High Auto Club, Jay Abitz, describes the process of setting up a Kiwanis for motor heads.

Step One: THE MISSION

▶ Not all members want to work in the shop. Some are there because they just love cars. It's important to develop a mission that includes hands-on car time, as well as activities that tap into other members' passions, like field trips to auto shows and dealerships.

Step Two: THE RULES

▶ Since some of the tools used in the garage can take a limb or even a life, all students are instructed in proper form before even picking them up. They're also repeatedly tested on Automotive Service Excellence rules.

Step Three: THE TASK

▶ No matter how impressive your students seem, start small and anticipate challenges. Motorcycles make great first projects because they are cheap, simply designed, and don't take up much garage space. Stay away from rust and jalopies. Replacing parts adds up quick.

Step Four: THE MONEY

▶ Ask members for money and you'll lose them. Instead, fund your club with grants and special events (car washes, winter maintenance checkups). The most important support will come from your community, so network with local dealerships, repair shops, and philanthropic organizations.



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► bumper, and demonstrate his chops at welding, all within four hours. Walrath says he wants to start an auto-restoration business, speaking as if that's a hypothetical. But this is actually the game plan, with his parents helping him set up a business once he graduates. I learn this not from Walrath but from his friend Dan Vosberg, who graduated last year and plans to work at Walrath's shop. "Yeah, that's actually happening," Walrath admits. "I didn't want to seem like I was bragging or something."

While I'm talking with Walrath, he fires up the Buick Grand National that he brought to the car show, and the car promptly coughs off its left valve cover vent, the gasket splitting in two as it falls onto the fender well. Walrath calmly seats the gasket back in the cap, aligning the two halves and screwing it back on. Not a major fix, but one he executed without even thinking about it. If it had been my car, I would've already been on my way to AutoZone by now, hunting for part numbers. This is a guy, I imagine, who will not have much use for roadside-assistance programs.

Nor will the other graduates of the Freedom Auto Club, regardless of whether they ever go pro. And that's a big part of the appeal, one that transcends cars, really—in a different age, we could be talking about shoeing horses or rebuilding cotton gins. The principle is the same: Given the right knowledge and the right equipment, this opaque expertise is within your grasp. Mr. Abitz will hand you a grinder, and you're going to learn how to find metal under that body filler. No way to it but to do it.

"At some point I decided every guy should know how to change his own oil," Lucier, the skater, tells me. "It's calming, working on cars. And then when you're done, you can look at it and say, I did that. I helped create this." Maybe you end up with a few tiger stripes here and there, but you're on your way to something wonderful. 

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BICYCLE COMMUTING

More than 800,000 people in the United States travel to work by bike. If getting fit and saving money sound appealing, here's how to do it right.



Pick Your Bike

► THE ROUTE

Before you buy a bike, you need to know your route. Go to Google Maps and your city's official website to locate bike lanes. Better, find bicycle-only pathways. Besides avoiding cars altogether, you can keep momentum, which means less energy spent stopping and starting.

With your route chosen, drive it to see how many hills you'll need to climb and to get an idea of mileage. This will affect the type of bike you choose. If you're like the majority of people in the United States and will be riding 20 miles or less to work, a hybrid or fitness bike is ideal. These have the light frames and narrow tires that make road bikes fast, but with flat handlebars for a comfortable, upright riding posture.

► THE PURCHASE

Avoid shopping online. Instead, buy from a local bike shop with a good reputation. Not only will they make sure you get a proper fit but usually there are perks, like the ability to swap out parts, and free tune-ups later. Plan to spend at least \$500, and add components as needed. In Seattle, disc brakes and fenders will help you stop when it's wet and keep mud off your clothes. In Phoenix those parts are just extra weight.

THE CHECKLIST: ARE YOU READY TO START BIKE COMMUTING? All must apply.



You know how to ride a bike.



You are not averse to moderate exercise.



You won't brag about saving the world.



You will adhere to bike laws—most of the time.



You are prepared to slap a car hood if need be.



You don't care what a bike helmet will do to your hair.

HOW TO GET STARTED IN . . .

► THE ULTIMATE COMMUTER BIKE: Trek 7.2 FX (\$490)

Wildly popular because of the smooth-riding steel fork and quality Shimano drivetrain. The 7.2 FX also comes with Bontrager H2 Hard-Case Lite tires that'll resist punctures and last for thousands of miles when properly inflated. The frame is set up to be a canvas for add-ons like fenders and a rear rack, the latter of which we highly recommend for any commuter. Also, at about 30 pounds, the bike is light enough to carry up stairs.



WHAT ABOUT . . .



Folding Bikes?

Great for city dwellers, these collapse small enough to fit in a taxi trunk or under your table at a café. The small wheels and foldable frame mean you lose comfort and speed, but companies like Tern engineer for increased torque and rigidity.

E-Bikes?

The onboard batteries that give electric bikes extra pedaling power make them heavy and expensive. Best for hilly routes or to avoid sweating. Important: Make sure e-bikes are legal where you live. They've been banned in some cities.

Bike Sharing?

A popular option that lets you check out and return bikes at stations throughout a city. Annual memberships range from around \$60 to \$150. All you need is your own helmet. Best for those who don't want the hassle of upkeep.



Gear Up

► THE ESSENTIALS

Helmet: More than half of bicycle-related hospitalizations and deaths are due to head injuries, so wearing a helmet isn't optional. Find one with CPSC certification. We like the **Giro Sutton MIPS** (\$100), which is layered so that the shell and interior lining shift around the head when struck, diffusing the impact.



Lights: Don't skimp here, either—cheap lights don't have enough lumens to be visible at a long distance and aren't as reliable or durable. The weatherproof **Cygolite Metro 400/Hotshot 2W** (\$80) combo pack has 4 watts for the headlight and 2 for the taillight, so you'll be easy to spot.



► INVEST IN GOOD PANTS

Wearing regular pants, which don't stretch, forces your legs to work harder, and regular tailoring will be tight around your quads. There are all kinds of cycling pants, but some companies now use just enough polyester to let your legs move freely while still providing the look of classic trousers. **Lululemon's** more formal **Commission Pant** (\$128) flexes at the knee, and zippered pockets ensure that you won't lose your keys or wallet. They're a huge upgrade in comfort, and your colleagues will have no idea.



► DON'T GO MESSENGER

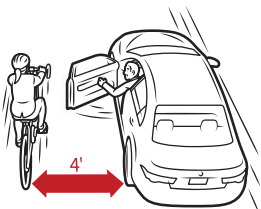
Unless you need quick access to your stuff while riding, forgo a messenger bag for a pannier, which attaches to a bike's rear rack without blocking the taillight. Even messenger bags and backpacks designed with space for airflow across your back leave you sweaty where the shoulder straps fall. They also have less interior space and will tire you out faster. Panniers like those from **Ortlieb** (\$180 per pair) have a full clip to securely attach to the rack (regular hooks can get dislodged on bumpy roads) and are waterproof.



Survive the Commute

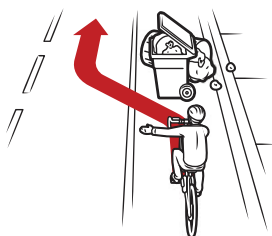
BEST PRACTICES FOR RIDING IN TRAFFIC

Even though bike lanes are being added to cities around the U.S., cars are still very much a part of the equation. Here's how to coexist.



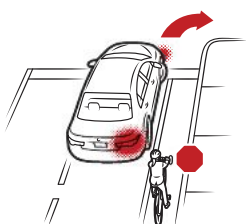
► POSITIONING

In a bike lane or on the road, keep as much distance between you and parked cars as possible. Getting "doored" is a common accident that happens when a driver-side door opens unexpectedly. Riding more slowly and staying alert will help you avoid this.



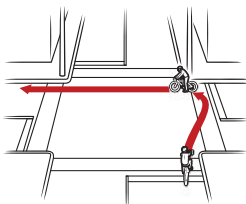
► MERGING WITH TRAFFIC

If there's something blocking your path, signal with your arm, wait for cars to pass, and merge into traffic like a car. If there is no bike lane, riding in the traffic flow, not to the right, is ideal and sometimes even the law. It makes you more visible and less likely to get hit.



► NEGOTIATING INTERSECTIONS, TWO WAYS

1. If you're to the right of the cars, stay behind the first car, even if you're on the side in a bike lane. This will help you avoid getting "right-hooked" by a car's unexpected right turn. When possible, bike in the traffic stream.



2. When a left-hand turn looks dangerous, cross the intersection, then stop at the far-right curb. When the light changes, cross the street like a pedestrian.



Maintain Your Bike

► DAILY

Checking the tire pressure every few days will save you from flats caused by underinflation. Use a floor pump, and keep the pressure within 10 psi of the number written on the sidewall of the tire. If the tire feels squishy, add air.

► MONTHLY

Lubricate the chain with climate-specific bike lubricant (twice a month in wet weather). With the bike upside down, hold a rag against the chain while turning the pedals. Lightly apply lubricant onto the chain. Wipe off excess.

► YEARLY

If you ride regularly, have your bike shop do an annual tune-up. Replacing parts like brake cables is tricky, and fixing skipping gears or misaligned wheels requires special tools. Improperly reassembling these parts can ruin the bearings.



Secure Your Bike



► HOW TO PROPERLY LOCK YOUR BIKE

No lock will survive a determined and well-equipped criminal, but the proper equipment and locking technique mean a thief will pass your bike over for one that looks a little easier to steal. Start with a serious U-lock such as **Kryptonite's New York Lock Standard** (\$93), which will withstand wire cutters and grinders but is more manageable than heavy chains. Then supplement the U-lock with a cable lock (pictured above) to protect your wheels. If you're locking up in a sketchy area, Pinhead makes locks that require keys for seats and quick-release wheels, which are both easy to steal.

BIKE TO A MEETING—WITHOUT GETTING FIRED

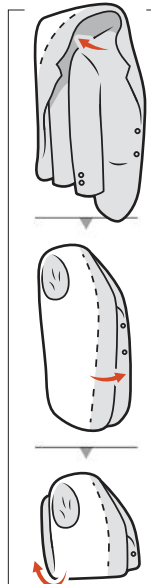
Don't let work attire stop you from commuting.

1. Leave yourself extra time. Besides getting an opportunity to cool down after arriving, you can pace yourself and sweat less, coasting as often as possible.

2. Wear an undershirt, ideally made of at least 90 percent merino wool. Natural fibers breathe better than gym-ready synthetics, which will keep your skin dry but can hold on to bad odors. While riding, unbutton your shirt Hasselhoff-style for ventilation.

3. White, navy, black, and patterns hide sweat stains. Bright blues and gray show them. If you're worried about odor and don't have a shower at work, hand sanitizer under your arms works in a pinch. Seriously.

4. Fold your blazer inside out and stash it in your pannier like so: ►



TIP!

BEWARE THE SUCKER POLE
Securing your bike to a structure that can be disassembled makes locking up moot. Avoid bait poles that have ground bolts already removed by bike thieves and rickety construction scaffolding.

So long as there continue to be cowboys and herders moving cattle and flocks of sheep across stretches of the American West for four or five months out of the year, there will be the canvas Colorado Range Tent.

The modified tepee in thick cotton fabric—the same material that made up the sails of the ships that first brought settlers to the U.S. and covered the wagons that shuttled them westward—remains the preferred shelter of the modern cowboy. It's for those professional operations on the range that the Denver Tent Co. takes most orders for its Cowboy Tipi. Hunters and everyday campers make up the rest. Denver Tent has been at it since 1890, having popped up among hundreds of other canvas and tent companies during the great expansion westward in the second half of the 19th century. In 2005 Kevin and Laurie Womer, the owners of Denver Tent, bought their longtime neighbor and rival the Colorado Tent Co. and with it the legendary handmade range tent. The canvas fabric for each tent is still cut by a 30-year veteran of the trade.

The range tent itself, which starts at \$289, is a hybrid of a traditional Cheyenne tepee and the large, walled sportsmen's tent used by the likes of Teddy Roosevelt during his excursions out west. The square base and sloping sides don't require an extensive frame, just two external poles. You could just as easily use two long branches you find out in the woods or tie the top of the tent to a low-hanging tree branch and stake down the base. A floor is sewn into the bottom, and the tent is small enough that it packs down to fit conveniently into the trunk of a car. Or on the back of a horse.

It's easy to romanticize, but the tent and the material have lasted, and remain part of the ranching life primarily through functionality. The tight weave of 10-ounce army duck canvas makes the Colorado Range Tent virtually water-repellent and fire-resistant. It's sturdy enough to function as a four-season shelter yet still breathable. And it's the strength of the canvas that allows range tents to last two or three generations, for real cowboys and imaginary ones camping out in the backyard alike.

—MATT GOULET

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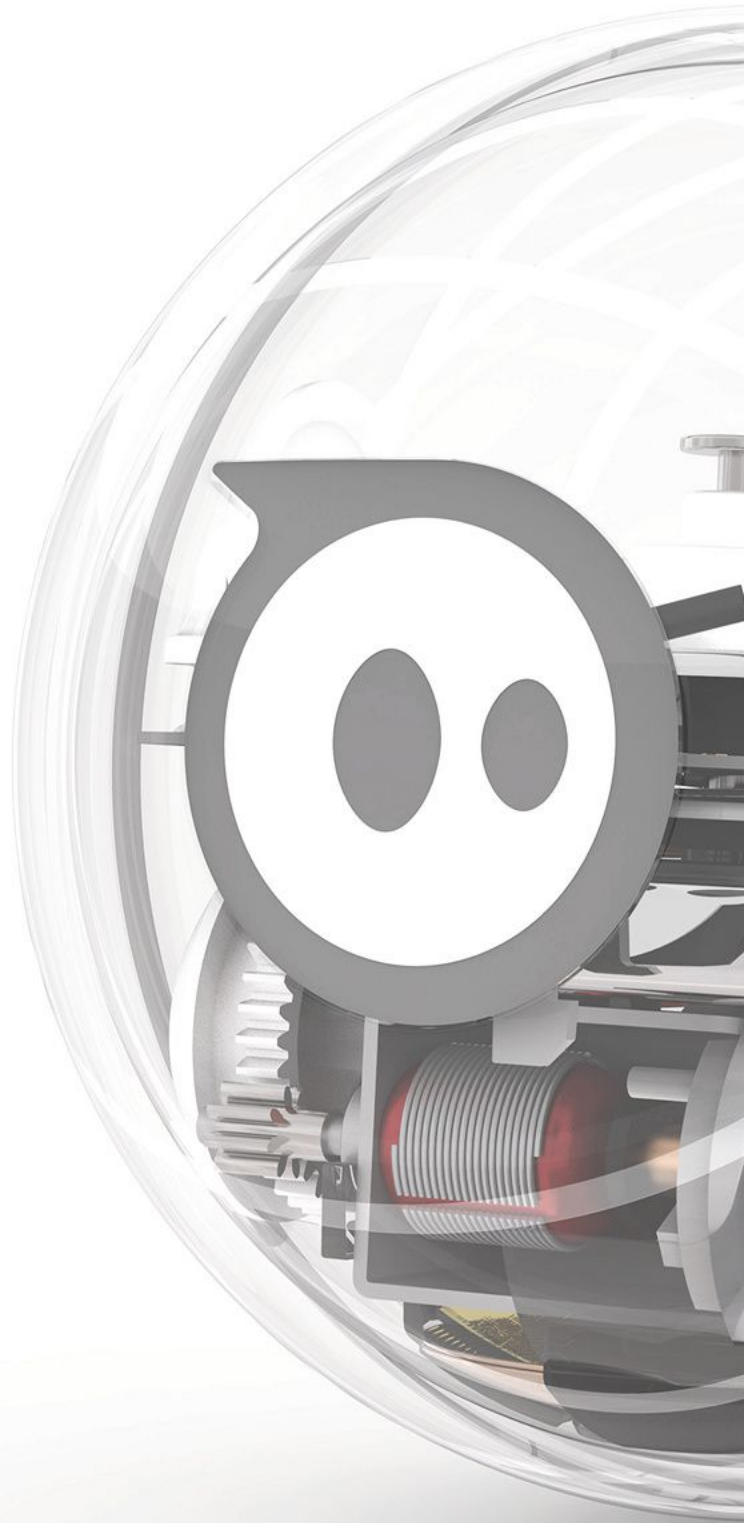


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Before you finish reading the next 12 pages, you will want to build something. Maybe it'll be one of the ideas in this issue. A smoker made out of an old wine barrel. A backyard table with a cooler built right in, saving all those seconds you used to waste walking to the Coleman. A new way to charge your cellphone while you're riding a motorcycle or cooking dinner. A canoe, if you happen to have a lot of time on your hands. Or maybe it's something else. It doesn't matter to us. In this, our second annual guide to making anything (or at least anything we can think of), our goal remains the same. We want to inspire you. We want to tap into that innate desire to create. We want to get you to do something that humans have been doing ever since we got these opposable thumbs. And we want to make backyard drinking even easier, one cooler-table at a time.

**Popular
Mechanics**

A BOW

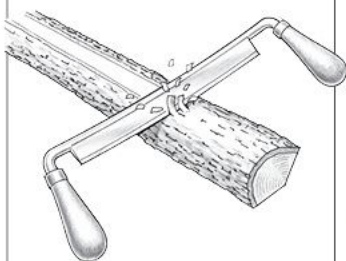
HOW TO MAKE

It starts with the right tree.

After a compound bow failed him on a turkey hunt more than a decade ago, 29-year-old Michael Spink of Spink Wooden Bows in Pocahontas, Arkansas, started making his own wooden bows by hand. He walked us through the process of crafting a 68-inch Native American longbow.

—ANDREW DEL-COLLE

and mark the shape of the bow's broadside. For a



Native American longbow, the 5 inches in the center should be narrower than the limbs—1¼ inches across, widening out to about 1½ inches. About 19 inches from the midpoint, taper down the limb to end with ½-inch-wide tips (A).

5 With a drawknife or band saw, refine the shape. Use a pocketknife to finish things off.

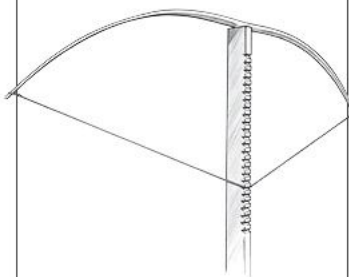
6 Lay the bow flat and taper the sides of the limbs with a drawknife. The middle 5 inches, which will be your grip, should be ¾ inch thick, tapering off to ½ inch when you reach the ends (B).

7 Use a chainsaw file to make string grooves at a 45-degree angle on the outside of both tips, about ½ inch from each end. On the bottom limb, make an extra set of grooves for the bow stringer, a separate string used to bend the bow for stringing.



8 Sand down the edges and tips and smooth the front and back surfaces.

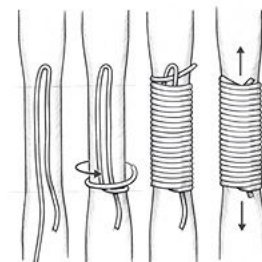
Then, with one tip of the bow against the ground, apply pressure to the top to create a slight bend—this is called floor tilting—inspecting the bow for any cracks or imperfections. If you see anything other than small cracks on the front, you'll have to start over with a new piece of wood.



9 Create a tiller tree (above) to test your bow's flexibility. Vertically secure a 2 x 4 to the wall. Starting 5 inches from the top, make a horizontal notch with a Skilsaw every inch until you reach 30 inches. String the bow loosely with parachute cord, center it on the top of the tree, and slowly move the string down the notches until it reaches the 28-inch mark, a typical full draw. At each step look for unevenness in the bend of the limbs. If they don't bend equally, even them up by shaving from the side that doesn't bend as much.

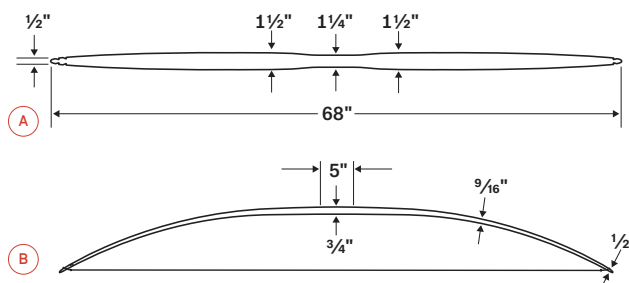
10 Shorten the parachute cord to make a small bend in the bow (5 inches between the bow center and the string). Repeatedly draw the bow in a mirror to see which side remains slightly stiffer. The stiffer limb will be your lower limb. Once you identify it, use a sander to create a shallow indentation above the handle to the right or left, depending on which hand you use to shoot, for the arrow.

11 Sand and finish the bow. Hunters may want to use a dark stain because it's harder for animals to see.



12 Once the bow has been stained, dried, and sealed, wrap the 5 inches of handle with hemp cord using a whipping technique (above). Apply a light coat of glue, such as Titebond III, and let dry.

13 Create your final bow-string using a new length of B-50 bowstringing material. A properly strung longbow should have enough bend to leave roughly 7 inches between the bow and the string.



1 Find your tree. Avoid weaker woods such as pine and willow in favor of hickory, oak, and maple. Look for a diameter of at least 8 inches, which will require less carving. (Because bows are made from vertical slices of the tree, on a smaller tree the arc of the outside edge—the part that becomes the back of your bow—will be more pronounced, requiring more shaving to flatten it out.)

2 Cut and split the tree. An 8-inch tree provides six or seven bow staves. Leave enough room on the end of each stave to cut off roughly 6 inches, where the wood might have cracks. (For example, a 68-inch bow needs at least a 6½-foot piece of wood.) Keep the stave roughly 1¼ inches wide from tip to tip and 1 inch thick. Leave the bark on to reduce cracking as the wood dries.

3 Let the wood dry. This typically takes at least three or four weeks but can be up to a year. (If you want to be sure, buy a moisture meter and wait for a readout of 11 or 12 percent.) The most flexible wood will warp into a bend called a reflex.

4 Debark your bow with a drawknife (below)

Once you master the longbow, this more complicated pyramid-style bow is waiting for you.



AN ENTRANCE

1. Wait for a new song or a long silence.
2. Throw open the door. Double doors are good. Saloon doors are ideal.
3. Smile. Scan the room and point toward anyone making eye contact.

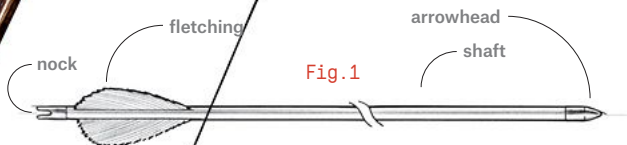


Fig. 1

HOW TO MAKE

An Arrow

It makes the bow a lot more fun.

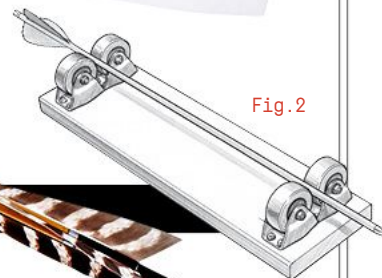


Fig. 2

While you can cut your own shafts, you don't want to. It's too complicated, and even the smallest imprecision can throw off your shot. Which means making your own arrows is really more of a process of assembly than of construction.

—LARA SOROKANICH



Paul Jalon of Elite Arrows in Bloomfield Hills, Michigan, has crafted his own arrows since 1952. They've been used to win 24 International Bowhunting Organization World Championships.

1 Shaft diameter is determined by the weight of your bow and other factors. Consult a spine chart, such as the one on 3riversarchery.com, to find the appropriate diameter, then order a set of matched wooden shafts (\$35 to \$50 for a dozen). Jalon prefers to use Port Orford cedar, but Sitka spruce and Douglas fir work too. You'll also need nocks (about \$10 per dozen; size is based on shaft diameter), a fletching jig (\$35 to \$90), a taper tool (less than \$10; size based on shaft diameter), and archery feathers (about \$15 per dozen). (See fig. 1.) Turkey feathers are the industry standard because of their thickness and consistency.

2 Wipe the shafts down with acetone to remove any sap, then lightly sand them.

3 Use the taper tool, which resembles an oversized pencil sharpener, to taper one end of the shaft to fit your nock. (Taper tools make both 5- and 11-degree tapers. Use the 11-degree taper for the nock.)

4 Roll the shaft in an arrow spinner to find any bends. (You can build a simple version yourself using four casters. See fig. 2.) Treat any curves by holding the arrow firmly on a flat surface and running the body of a screwdriver over it from end to

end. This should force the wood to lie flat. Repeat until the shaft looks straight in the spinner. This is the most important step, so be sure to get it right before moving on.

5 Seal your shafts by brushing them with acrylic floor finish. Let them dry for three to four hours, then sand lightly. Repeat for three total coats.

6 Use clear fletching cement or instant glue to attach a nock to the tapered end of the shaft. Then use a fletching jig (Google it) to attach three or four precut feathers, and let dry.

7 Place the uncut arrow on your bow and draw it back. Have someone else mark the arrow an inch in front of the bow handle. Cut the arrow at the mark, taper the cut end, and apply your point or broadhead using hot glue or epoxy. Let dry.



HOW TO MAKE

A Mattress

Many commercial mattresses contain fire-retardant chemicals, which is useful if you're ever in a fire. But throughout the life of the mattress, those chemicals are gradually released into the air in a process called off-gassing, so the rest of the time they're actually a bad thing. Especially for kids.

Making a mattress is actually quite easy. Just buy a premade ticking, or cover, and stuff it with two filling layers—one for support, one for comfort—zip it up, shake it to help settle and align the contents, and lie down. The only real decision is the filling. Deborah Brenton of diynaturalbedding.com, where you can buy all of these materials, including the ticking, explains.

A. NATURAL LATEX

The most common choice as a bottom support layer. You'll need anywhere from 3 to 7 inches (\$300 to \$500) depending on your weight. For a softer mattress, use three 3-inch layers. Hard at the bottom, medium in the middle, and soft on top.

B. WOOL TOPPER

A good comfort layer if you sleep on your back or your stomach and thus tend toward slightly firmer beds. The 10½ pounds of wool you'll need to fill a queen costs \$425.

C. KAPOK FIBER

This fluff-like material comes from seed pods. It's far more commonly used in India, and would be an exotic choice for a firm sleeping surface. You'll need about 61 pounds (\$7 a pound) for a queen-sized bed.

D. WOOL FLAKE

A tough, dense material that self-regulates temperature. Makes a firm to hard bed. Fifty pounds provides 6 inches of cushioning in a queen and costs \$518. (You'll want to tuft it to the ticking to avoid bunching. Brush up on your sewing skills.)

HOW TO MAKE

A Forest

Johnny Appleseed had his little satchel, determination, and patience for long walks. Lauren Fletcher has a drone.



Whether it's from clear-cutting or wildfires, more than 50,000 square miles of forests are lost every year. Regardless of the billions of dollars spent, it's hard to keep up. But Lauren Fletcher, a former NASA engineer and the founder of BioCarbon Engineering, has a plan—and a device—that might help. This year his company announced a drone that will plant at a rate of ten trees per minute. That's 12 times as fast as human planters. A group of eight drones can plant a total of 36,000 trees in one day. And they can do it in practically any terrain.

The first step is finding a place in need of a forest. BioCarbon works with local governments, coal and oil companies, and local ecologists. Once a suitable location has been determined, the company uses satellite mapping programs and its own mapping drones to create a detailed 3D map of the area. Then the planting drones are sent in. Each device holds 500 biodegradable seed-pod cartridges, which it fires using pressurized air, lodging each one 3 to 5 inches in the soil. Upon impact, the cartridge breaks open and the seed is planted. Lab tests have shown a 70 to 80 percent chance of survival.

Fletcher plans on planting his first forest by the end of the year in Brazil or South Africa, and by 2020, he hopes to plant 1 billion trees per year. Even that isn't enough to completely counter deforestation, but it will provide plenty of clean air, animal habitats, and tire swings.

—CAMERON JOHNSON

A USB CHARGER FOR A MOTORCYCLE

You can add a USB charger to almost anything with electronics—your alarm clock, coffee machine, fridge, or aquarium. Since I'm a motorcycle guy, I installed one on my bike, but these instructions are adaptable to pretty much anything

with a power supply. Just be sure to unplug whatever it is before you start tinkering.

—NIAL MCGAUGHEY

1 Purchase the right USB charger. You want a USB port with electronics that limit output to 5 volts so you don't fry your device. Expect to spend around ten dollars.

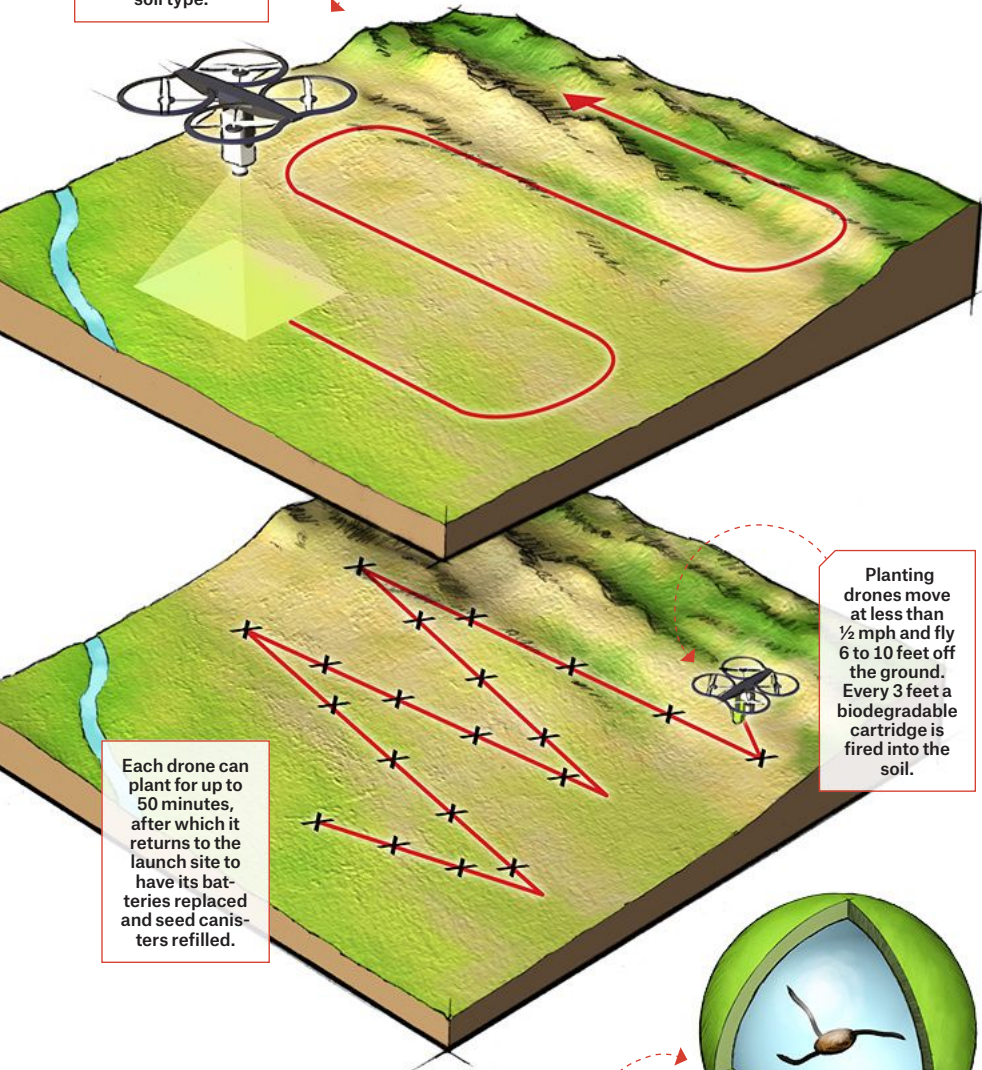
2 Route the wiring. The charger needs to be wired

to the power source with a fuse in between (fig. 1). On an appliance, you're looking for a 12-volt line to tap into—something that leads to a lightbulb, like the one in an oven or fridge, is a safe bet. On my motorcycle I wired to the battery and used a standard automotive fuse. Choose the right one by taking the current (in milliamps) required by your device (about 900 mA for most cellphones) and multiplying it by 1.5.



Nial McGaughey runs Hovercraft Amps in Portland, Oregon.

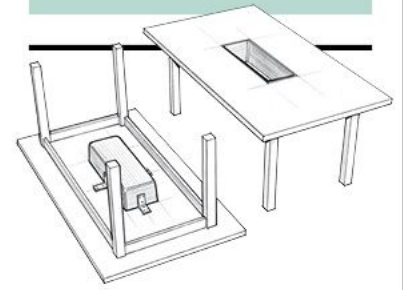
A mapping drone creates an optimized planting pattern based on topography and soil type.



Each drone can plant for up to 50 minutes, after which it returns to the launch site to have its batteries replaced and seed canisters refilled.

Planting drones move at less than 1/2 mph and fly 6 to 10 feet off the ground. Every 3 feet a biodegradable cartridge is fired into the soil.

Biodegradable cartridges hold pregerminated seeds covered in a nutrient-rich hydrogel to help absorb moisture as the seed establishes itself in the soil.



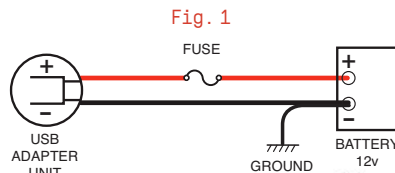
HOW TO MAKE

A Table With a Built-in Cooler

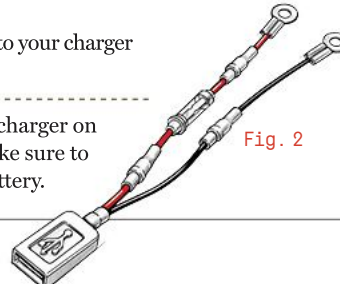
You can improve nearly any outdoor table by adding a built-in cooler. Dan Knor of East Petersburg, Pennsylvania, added a basin to this table, which he made out of 1 x 2s, 2 x 3s, and 2 x 6s, by cutting a hole in the middle and dropping in a window box for planting flowers. The box tapers down for a tight fit, and since it's not affixed to the table, emptying the ice and water at the end of the night is as simple as picking the box up and dumping it out. Although Knor didn't need a bracketing system, you'll want one if you choose a larger basin. (See below.)

- 1 Find a metal box big enough to accommodate your drinking habit.
- 2 Measure your table to find the center and cut a hole in the dimensions of the metal box.
- 3 If the box has a lip, it will make for a nice finish on the table. If not, you'll need to permanently mount it under the table, similar to an undermount sink.
- 4 Attach four L-brackets to the bottom of the table and the basin.
- 5 Use a metal bit to drill a drainage hole in one of the bottom corners of the basin. Plug it with a wine cork.
- 6 Fill the basin with ice and your favorite beverages.

- 3 **Connect to the power source.** Ring terminals for motorcycle batteries come in standard sizes. Hook the ring terminals to the battery and solder the other end—or connect it using push-on terminals (fig. 2)—through the fuse and onto the charger. On an appliance you splice into that 12-volt line. Use a piggyback-style push-on terminal, which splits the line in two and will get electricity to your charger without sacrificing the lightbulb.



- 4 **Charge.** Plug in your device. If you've installed the charger on something battery-powered (like a motorcycle), make sure to unplug it when you're done, otherwise you'll drain the battery.



HOW TO MAKE

A CNC Router

Ehad Bridgewater makes great new things out of great old things. A blue-collar metalworker from St. Francis, Wisconsin, with an artistic disposition, he transforms classic cast-off tools into modern shop gear. His CNC router (right) began life as a 1946 Delta drill press, which he rescued from a trash heap outside a machine shop in Milwaukee, where it was manufactured. The basic process of each machine isn't that different, just reversed. A drill press uses a movable drill to puncture a stationary object. A CNC router uses computer-controlled stepper motors to move an object as it's cut by a stationary tool. Bridgewater walked us through some of the foundering, boring, foam cutting, and 3D printing it took to update this 69-year-old machine for 21st-century use.

—KEVIN DUPZYK



The rails, belts, and pulleys were pilfered from a ten-year-old Stratasys Prodigy Plus 3D printer. Bridgewater bored them to fit the press with his own World War II-era lathe.

The brains of the router are a decade-old computer Bridgewater poached from a previous employer when it upgraded its hardware.

Bridgewater made the cast-iron bed mount himself. He used a CNC router to cut a foam pattern before switching to traditional techniques, turning the pattern into a sand mold that was filled with molten iron.

The bed of the router is scrap acrylic from laser cutting, purchased from a local plastics company.

The black plastic bearing housings that allow the bed to move were prototyped on a home-made 3D printer and finalized on a MakerBot 2X. Three skateboard bearings in each housing help the bed move smoothly along the rails.

Like the drill press, the post and stand are original Delta parts, from a Craigslist find.

The electronics are housed in an Allen-Bradley enclosure, saved from an exhaust hood scrapped during a building renovation.

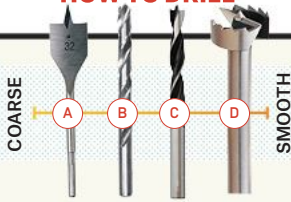
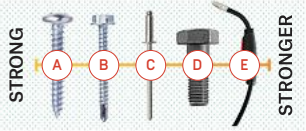
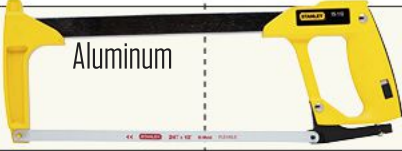


A
STEAM-FREE
MIRROR

1. Before a shower, spray a dollop of cheap shaving cream, like Barbasol, on your bathroom mirror.
2. Wipe it off with a paper towel.
3. Admire your work, and yourself.

LITERALLY ANYTHING

An oversimplified guide to cutting, drilling, and affixing the most common project materials.

MATERIAL	HOW TO CUT	HOW TO DRILL	HOW TO FASTEN
Softwood, Hardwood	Rip on a table saw with an 18- or 24-tooth blade [A]. Crosscut with 50-tooth or a 60-tooth alternate top bevel [ATB] combination blade [B]. 	 COARSE ————— SMOOTH A. spade B. 118-degree twist [118-degree refers to the angle of the point of the bit] C. brad-point D. Forstner	Use wood glue when making furniture, carpenter's glue for heavier-duty construction projects, finish nails for trim and furniture, and nuts and bolts for maximum holding power. 
Construction Lumber	You want speed, not necessarily a clean cut. Use a 24-tooth blade on a circular saw.	A spade bit for large holes or a power-feed bit	Common nails, bolts, or construction adhesive [especially when called for in the building code]
Plywood	An all-around blade like the 80-tooth ATB 	SMALLER HOLES: twist drill bit LARGER HOLES: holesaw	Coarse-thread wood screws, wood glue, or construction adhesive
Steel	SMALLER ITEMS: 14- to 32-tooth hacksaw LARGER CUTS: circular saw with 48- or 70-tooth titanium-carbide blade SHEETS: abrasive blade. Wear safety equipment. They're noisy and throw a rooster tail of sparks. 	ORDINARY STEEL: 118-degree twist drill bit HARDENED STEEL: cobalt high-speed steel [HSS] with a 135-degree split-point tip 	 STRONG ————— STRONGER A. sheet-metal screw B. hexhead self-tapping screw C. blind rivet D. bolt E. welding torch [See our June issue for how to weld.]
Aluminum	A coarse, 18-tooth hacksaw 	118-degree HSS bit	Blind rivet or welding gun
Concrete	Segmented- or continuous-rim diamond abrasive blade	Masonry bit	Concrete screw or specialty concrete adhesive
PVC	80-tooth triple-chip-grind [TCG] blade	118-degree twist drill bit	PVC-pipe primer and adhesive 

A Canoe

HOW TO BUILD

Kerry Bishé lives in Manhattan, and last year she wanted to build a canoe. Manhattan is an island, yet it must be one of the worst places in the country to own a canoe. Where would you use it? The few protected inlets are overrun by kayaking classes, and everything else is a highly trafficked thoroughfare of commercial ships, banker-owned power yachts, ferries, and terrible dinner-cruise boats. And even if you could somehow work your way around all that—find a good place to put in for a relaxing paddle among the waves and occasional glob of coagulated pollution—where would you keep it?

These were the kinds of questions Bishé faced from her classmates on the first day at Chesapeake Light Craft in Annapolis, Maryland, where, for \$1,975, she'd enrolled in a five-day program to build a 16-foot sassafras canoe. She didn't know the answers. And she didn't really care.

"It wasn't about having a boat and using it," the 31-year-old says. "It was about how hard it would be to make it. I wanted to do something that I might be really bad at." Bishé knows her way around tools, having grown up designing and building theater sets. But her day job isn't exactly one that would train her to build a watertight vessel. She's an actress. She was the charming hub of an attempt to reinvigorate *Scrubs* with a new class of doctors in its final season, starred as one of the rescued embassy workers in Ben Affleck's Oscar-winning movie *Argo*, and plays the genius and delightful Donna Clark in AMC's drama about the 1980s personal-computing revolution, *Halt and Catch Fire*.

And now she's a boatbuilder. The process at CLC starts with a kit, although if you're so inclined, the \$99 plans include instructions for making the necessary pieces yourself. Students stitch together a pile of boards with copper wires to form the side panels of the boat. "Your hands hurt" after twisting all those wires, Bishé says. "I'm really lucky that it started looking like a boat at the end of the second day. Otherwise I'm sure I would have given up." The next three days are spent gluing the panels together, cutting away those wires, and sanding, fiberglassing, and sealing the boat.

It's hard work, but that was exactly what Bishé wanted. She wanted to do all the work herself, and to use the rote maneuvers as an excuse to think. Of course, she also wanted to end up with a boat. Something that would float. And she wanted to do it by her birthday. After the class, Bishé worked for ten days straight, adding layers of varnish, sanding, and finally painting. On her birthday last spring, Bishé put the canoe in the water. It floated. (Still does.)

Bishé hasn't figured out what she's going to do with the boat. For now, though, it hangs from the ceiling in her apartment. Even if she never puts it in the water again, Bishé can use her canoe every day—to remind herself that she can master a skill she thought she might be really bad at.

—PETER MARTIN

Bishé initially stored and finished the canoe on a lake in Great Barrington, Massachusetts.





Scrubs
2010



Argo
2012



Halt and Catch Fire
2015



HOW TO PAINT A SASSAFRAS CANOE

[THE TRADITIONAL WAY]

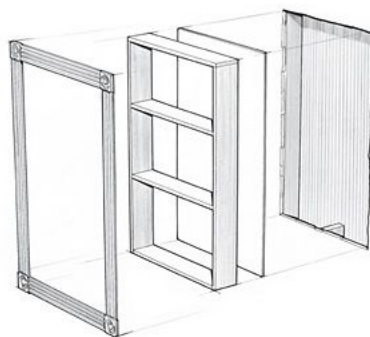
- 1 Prime the exterior.
- 2 Paint the exterior white, beige, gray, or some other light and neutral color. Bishé chose Interlux Brightside Polyurethane in Hatteras Off-White. After spending so much time making a boat with beautiful ridges where the panels overlap each other, don't cover up your work with a dark

paint. You may be tempted to simply varnish the boat, which is obviously fine, but the contrast between the painted outside and the varnished wood of the inside will be more striking. Also, paint hides any imperfections you may be worried about.

- 3 Varnish the interior, rails, and deck, sanding in between coats, for three coats.



For six ways to find new music on your phone, go to page 44.



1 Find two studs and make a 3 x 3-inch exploratory hole in the drywall between them to see if any wiring, plumbing, or ductwork is protected by the wall. If not, proceed.

2 Using the studs as the sides of your bookcase, mark the bookcase opening on the wall with a level, a tape measure, and a straightedge.

3 Use a drywall saw or an oscillating multitool to cut along the lines and remove the piece of wall.

4 Cover the rear surface with a thin sheet of plywood, and build a four-sided pine frame to fit the opening. It should be flush with the surface of the wall.

5 Paint the frame, plywood, and any shelves.

6 Insert the frame in the opening and attach it to the studs with screws. Add shelves using small brackets screwed through the frame and into the studs.

7 Install trim around the frame by nailing the vertical pieces to the studs and gluing horizontal pieces to the drywall.

HOW TO MAKE

A Bookcase Inside Your Wall

Depending on your home, there could be a good 4 to 6 inches of unused space behind your drywall. Here's one way to put it to good use.

HOW TO MAKE YOUR FRIENDS HAPPY

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HOW TO MAKE

Steak Sauce

BY CHEF
CHARLIE PALMER

Makes about 1 cup.

In a medium mixing bowl, **combine**:

- $\frac{3}{4}$ cup ketchup
 - $\frac{1}{4}$ cup Worcestershire sauce
 - 1 Tbsp molasses
 - 1 Tbsp apple cider vinegar
 - $\frac{1}{2}$ Tbsp soy sauce
 - 1 Tbsp orange juice
- Stir until smooth.

In a large pot, **sweat**:

- $\frac{1}{8}$ cup chopped onions
 - 1 tsp chopped garlic
 - 1 tsp chopped ginger
- Onions should be translucent.

Add in:

- 1 Tbsp light brown sugar
- $\frac{1}{8}$ tsp allspice
- $\frac{1}{2}$ tsp celery seed
- 1 tsp black pepper

Cook on low for about 2 minutes, stirring slowly, until the sugar begins to break down and melt.

Add the wet mixture to the pot and simmer for 1 hour.

Transfer to a blender and **puree**.

Let cool before serving.



Chef Charlie Palmer has won two James Beard Awards. He opened his first restaurant in New York City in 1988, and has since expanded his empire to include 13 more restaurants—including a new Charlie Palmer Steak in New York City—and three hotels.



A TOAST

1. Put down your notes and wing it.
2. Make sure Grandma isn't there before you work blue.
3. Keep it shorter than you want to.
4. Save the sweet stuff for the end.

1 Find an inflatable ball, such as a beach ball, a little smaller than you want the lampshade to be.

2 Pour a 10-ounce bottle of craft glue into a bowl. I used Mod Podge, but any brand that dries with a clear, matte finish will work.

3 Dilute with a quarter cup of water.

4 Cut twine into 4-foot lengths and swirl them around in the glue until they are fully coated. I used hemp and fluorescent-yellow mason twine from Home Depot.

5 Wrap the twine around the inflated ball, overlapping the different strands. Leave a 3-inch-diameter hole over the inflation valve of the ball. You'll use that to pull the ball out when the glue is dry. Also, that's where you'll hang your lightbulb.

6 Let dry overnight.

7 Deflate the ball and remove it from the lampshade. You'll have to do a bit of gentle prying to disengage it from the glued strings.

8 Affix the lampshade to a plug-in or hard-wired pendant light fixture, which you can find online or at Ikea. I cut a small hole in a yogurt-container lid to suspend my string ball around a lightbulb, but you might find a more elegant way to do this using wire or an aluminum sheet.

HOW TO MAKE

A Lampshade

You can make a lampshade out of pretty much anything—watered silk stretched over hammered coat hangers, corrugated steel, copper tubing strung together with wire . . . or twine and glue, like this one.

BY ANN QUIGLEY

HOW TO BUILD

A Smoker

You don't need a steel drum or a welding kit. Just a wine barrel, inspiration from Instructables, a few fire rocks, and two hours.

BY ROBERT VRABEL



HOW TO SMOKE A PORK BUTT

By Allan Benton,
BENTON'S
SMOKY
MOUNTAIN
COUNTRY
HAMS

1 Buy a whiskey or wine barrel from a local distillery, vineyard, or on eBay. (Standard 53-gallon barrels cost \$200 to \$300.)

2 Before cutting off the lid, drill self-tapping screws through the metal bands to fasten them to the staves. This will prevent having loose, shifting staves once you cut them off from the rest of the barrel. If your staves are wider than a couple inches, use two screws per stave for increased stability.

3 Cut the lid off the top of the barrel with a jigsaw at least 5 or 6 inches below the first band.

4 To create air intakes, drill three $\frac{3}{4}$ -inch holes between the second and third rings from the bottom. Screw $\frac{3}{4}$ -inch NPT nipple fittings into the holes, leaving some of the threads sticking out of the barrel so that you can add NPT end caps.

5 Drill a small hole for your temperature gauge in the lid. Make sure it's a snug fit.

6 Fasten a handle—any generic handle will do—to the top of the lid. Drill three holes in the lid, just big enough to fit three more $\frac{3}{4}$ -inch nipples. You'll add or remove their end caps to adjust the temperature during smoking.

7 Line the bottom of the barrel with fire bricks to contain heat. Without blocking any of the air intakes, stand bricks every 4 to 6 inches around the inside of the barrel. This frame

will support the bottom grate and serve as a cradle for your water pan.

8 Add the bottom grate. You'll place charcoal on top of the bottom grate, then wrap smoking chips for flavor in aluminum foil and place them directly on the charcoal.

9 Screw four 90-degree brackets along the inside top edge of the barrel. Place a grate on those brackets. This is where your meat will go.

10 Start with something easy, like pork butt (see right).

1

Buy a 7- to 8-pound bone-in Boston butt.

2

Combine coarse ground salt and coarse ground pepper, and rub it into the pork.

3

I'll start some hickory wood burning in the evening, let it get down to some nice, hot coals, and put those in the smoker with the meat.

4

Let it smoke all night, and by late morning, when you see the meat drawing away from the bone, it's ready.

5

Check the internal temperature (at least 145 degrees). Let it rest a few minutes. Add your favorite sauce and serve it up.



This smoker was built by Andy Northshield of North Salem, New York.

5

The computer creates more energy than some of its parts can withstand, so they are cooled through this external radiator.

1

Silicone tubes carry a mixture of distilled water and additive, the same kind used in radiators. The additive breaks down the water's surface tension, exposing more molecules to the heat from the circuit board. The heat is absorbed by the mixture and transported to the thermal tanks.

2

Brass plates about the size of index cards are bolted directly to the graphics cards, which reach temperatures of 210 degrees. The plates, called heat exchangers, draw heat without interrupting the circuit board's operations.

4

The organic phase-change material emits heat as it returns to a solid state. That heat is transferred from the tank by these silicone tubes to a basic fan-coil radiator that blows air over the coil, extracting heat and dispersing it into the room. The unit can also be plumbed to work with a water heater.

HOW TO USE

A Computer to Heat Your Home

If you've ever used a laptop on your actual lap, you know how hot computers can get. You could grab a pillow and protect your chances of fathering children, or, like Lawrence Orsini, an energy consultant in Brooklyn, New York, you could use that heat to warm your home. Orsini created a device he calls Henry—a working desktop computer that transfers the heat from a circuit board through a series of pipes and reservoirs and into his apartment, saving him hundreds of dollars each year and giving him something to look at in the living room other than the TV.

—HAN ZHANG



3

Heat energy collects in two sealed and pressurized 5-gallon metal tanks in the base. The tanks contain fatty acids and esters—organic phase-change material that shifts easily from liquid to solid and back as it harvests and disperses heat.



THINGS YOU SHOULD LET OTHER PEOPLE MAKE FOR YOU

croissants

diamonds

crossword puzzles

deodorant

fireworks

business cards

vaccines

child's car seat

diploma



SOLO

In the final story of our four-part series, the author goes after what he wanted all along, the thing man has wanted forever: to fly.

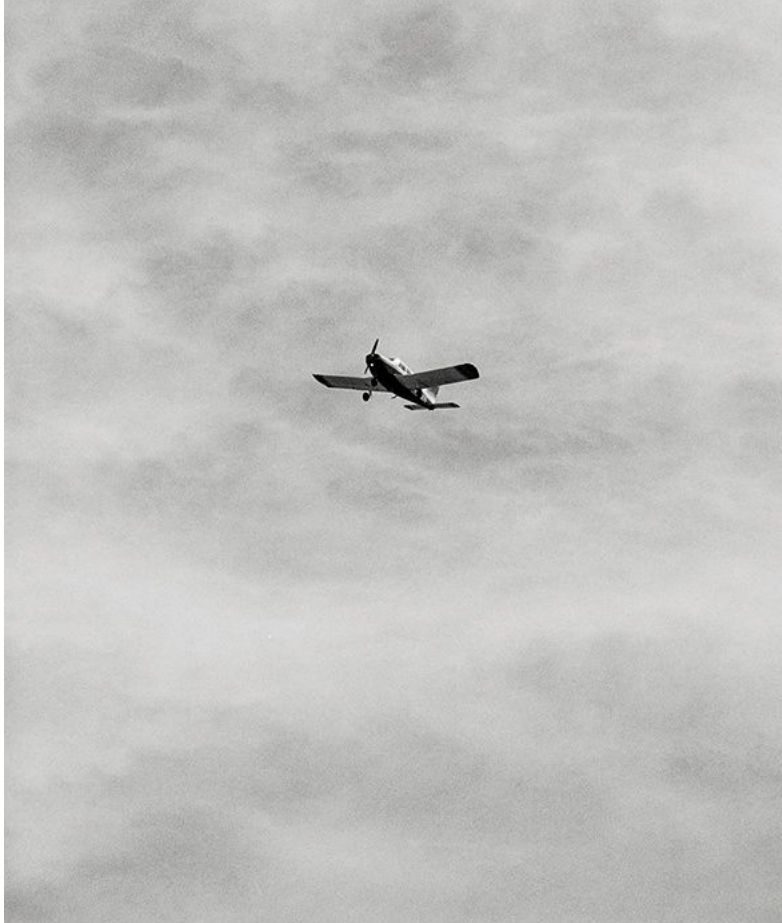
BY **JOSHUA FERRIS**
 PHOTOGRAPHS BY **DANIEL SHEA**

I'M NOT A PILOT. I'M A WRITER. I was commissioned by Popular Mechanics to write about learning to fly, a commission I agreed to after a few days of deliberation, mainly, and perversely, because I'm terrified of flying and I figured I'd have something to say. I had expressed a desire to fly solo, as the culminating event of my flying lessons with Tom Fischer of Fischer Aviation, but from the first moment of my first lesson, when I was quite out of my mind with disbelief and anxiety and regretting soulfully this awful decision, I did not think a solo flight likely at all.

Most days I had to encourage myself to do the adult thing and continue: to leave the apartment when I might have otherwise been at work on a novel, to face down the scorn of a resentful parking attendant and retrieve my Zipcar from the bowels of the nearest garage, to drive over the George Washington Bridge in the perilous midday traffic, to fill up the tank and eat on the go and be on time—all of the many everyday adult things I'd worked so hard my whole life to avoid. And then to submit again to the Piper Cherokee we called Six-Two Romeo, to the current condition of its engine and landing gear, to a faith in the diligence of mechanics and my own eyeballing inspections, to Tom Fischer's expertise and the expertise of all those circling the Caldwell Tower traffic pattern with us that day, and to my own undetermined fate. I did this throughout August, September, October, November, and December of last year, three times a week, as withering sun and heat turned to ice and snow, interrupted twice by weeklong business trips, by sickness and bad weather, and by the old yearning to write.

A single commercial flight, with its wobbling takeoff and changes in engine noise, was usually enough to convince me how wrong this whole enterprise was: the vast airports, the teleport-like travel times, the entire infrastructure upon which our interconnected and globalized world is so heavily premised. If I had been alive before human flight was an established matter of fact, I would not have been the man to gaze upon the bird and declare, By God, I can do that! I would have been the man who retreated from the doorway and turned back to the scene between two make-believe characters unfolding on his desk in a dark corner of the hut.

I was equipped with an overactive imagination, one prone to extremes and inclined toward the morbid, and so I can and do dwell often enough on my death and accommodate death's subconscious forays into my daily happiness, without having to go up in a plane. Death is often depicted in movies and in comic strips as coming for people, wearing his black cloak and carrying his black scythe and suddenly appearing beside the unsuspecting and the incredulous, but it was the opposite with me: involuntarily, burdensomely, I went thinking and sniffing after death many times a day, to try it on, to realize limits, to rage,



to attempt once more to comprehend the mortal arrangements of a puzzling world. Life was puzzling and it was hazardous and it was short. I could imagine a hundred ways of dying in my own house, in my bathrobe, while only reading the *Times* and eating a bowl of cereal. Why did I need to complicate matters by learning how to fly?

I wasn't flying because I got a great big Maverick-and-Goose thrill out of being up in the sky. Not until very late in the process did I consider the practical angle, the possibility of flying myself to Key West for the weekend and enjoying a weekend in Key West before flying myself home, because by that point my wife had come up with Tom and me in Six-Two Romeo and declared herself "scared shitless" for the entire two hours. "It was the most frightened I've ever been in my entire life," she said, forswearing ever going up in the air with me like that again, and if my wife wasn't going to fly down to Key West with me for the weekend, I wasn't going to go alone, so the practical angle, which didn't come to me until late anyway, wasn't the reason I agreed to fly.

I don't know why I agreed to learn how to fly. The truth is, I don't know why I do *anything*. I've been trying to understand, first, why I agreed to fly, and second, why I do anything at all, from the very moment I agreed to learn how to fly, because learning how to fly had a way of focusing my attention and forcing me to confront the certainty that I would die, which is the necessary backdrop to asking all sorts of questions about purpose and meaning and what makes life worth living.

The only reason I could possibly agree to learn to fly was so that I could write about it. I wouldn't have learned to fly just to fly. Writing, for me, was the reason life was worth living. What other people

did to get the most out of life, I did in the service of writing. Even if, as with the case of flying, the only way to get the most out of life was to risk dying. I comprehend fully the absurdity of this condition and readily admit that it makes no sense. And please understand me, I had a lot to live for. I had a wife and a son who make me very happy. I had just watched my father die in Chicago, at age seventy-five, after a long bout with cancer, and I really only wanted to come home and stay home and enjoy the company of my family and grieve. But after he died, I came home and began my flying lessons. It seemed to me that I went from the funeral home to the flight school, from the end of protection to the start of great peril.

I was always in good hands with Tom Fischer, who had more than nine thousand hours of flight time and possessed the confidence and demeanor of a general in the Air Force, but Tom would never be my father, who had zero hours of flight time and only ever wanted to take me to Wendy's for the dollar menu before we settled into a weekday matinee. At the end of my time with Tom, it was my intention to fly solo. I didn't want to solo, but I was writing about learning to fly, and when learning to fly, soloing was the inevitable dramatic conclusion. But when I'd imagine soloing, I'd imagine being a few thousand feet up in the air looking at the instruments that I still only half understood, at a control panel I could not interpret, in a perfect cone of death's white noise, muted, helpless, and uncommunicative, like my father on his deathbed in Park Ridge, Illinois.

For the first dozen lessons or so, when Tom and I would walk out together through the parking lot with the can in hand—the metallic logbook where flight time was recorded, which also contained the keys to Six-Two Romeo—I would be sick with apprehension.

Stepping inside Six-Two Romeo to retrieve the checklist and fuel-tester cup, walking around the plane doing the preflight check, getting back in and starting the propeller, taking down the

Joshua Ferris is the author of three novels, including *Then We Came to the End*, a finalist for the National Book Award, and *To Rise Again at a Decent Hour*, nominated for the prestigious Man Booker Prize the first year American writers were eligible to receive it. To read Joshua Ferris's "Learning to Fly" series in its entirety, go to popularmechanics.com/learningtofly.



ATIS data (weather conditions, runway availability), calling ground control for permission to taxi, and then taxiing to the runway, I was in a constant state of denial about what I was about to do. I was, in fact, about to race down a runway streaked violently with brake marks until I reached seventy miles an hour, then pull back on the yoke to lower the stabilator while applying right rudder to keep the plane steady as it entered the air, then rise over the wall of trees that stood at the end of the runway like a tribunal of final judges, and over the golf course that, still but five hundred vertical feet away, looked so mortally close, all while hoping for the continuation of a positive rate of climb entirely dependent upon an engine whose sudden sputtering and stalling out I was listening for every unfolding second.

But here's the good news I have to share with you, if, like me, you are afraid to fly: By taking off and landing in a small single-prop several times a day, sooner or later you stop being afraid. Perhaps not entirely, but by the time Tom and I took my wife up in the air and we came back down and she declared herself scared shitless, I could only laugh and laugh, because I understood so well exactly where she was coming from, but I was no longer there. My fear just wasn't there, it was no longer equal to hers, where once it had been even more potent. I had been taking lessons for two or three months by then, and without realizing it, I had, over time, by systematic exposure to episode after episode of terror, damn near completely lost my fear of flying.

But to solo? The word itself made me shudder with dread. I was worried that I would panic, or choke, or suddenly blank on something essential. Blanking wasn't unprecedented. Take the time I tried to land on the runway while still flying too high and too fast. It was a beautiful day, cold but bright, with good visibility. We were at the end of October. As we went up, the trees, whose leaves had turned by then, extended for miles and looked, from that unique vantage, like the bunched feathers of some fantastically colored

thing. All of New Jersey had a feathery shimmer that day, cut away here and there by the still eye of a lake or an empty baseball field, and in the distance, the Manhattan skyline stood geometrically erect like so many assorted math supplies.

Tom and I had run through maneuvers over the onion fields—slow flight, steep turns, and stalls—before doing simulated engine-out landings at the uncontrolled Orange County Airport just north of Caldwell. Tom would reach out as we approached the runway and take all the power out of Six-Two Romeo, the cockpit would fill with silence, and the plane would quickly start to sink, and by this I understood that we were practicing how to land during catastrophic engine failure. To reach the runway and to set the wheels down safely and gently, I was allowed to use only that glide still inhering in the plane.

I did this moderately successfully a number of times, and then it was time to head back to Caldwell and call it a day. I was really pleased by how I had handled those simulated engine-out landings, and had no particular anxiety about the final landing of the day, since that would be done with the benefit of power. But I hadn't counted on the confusion, the spatial muddle that occurs when, for the previous two hours, you've been playing around in a wide swath of practice area and then abruptly enter a tightly regulated traffic pattern like the one at Caldwell, where strict rules for altitude, speed, and landing order are dictated by an unforgiving tower. I found myself coming in too close to the runway during the leg of the descent called the downwind because I couldn't quite settle down or get my bearings, and a crowded downwind pretty much determined that my next leg, the base leg, which is the leg you

travel just before you turn one final time and head directly at the runway, was going to be super short if I hoped not to overshoot the runway. In other words, I left myself with no time to descend or slow down on my final approach to the runway. I didn't recognize what I was seeing, and without a familiar sight picture, I blanked on how to slow and how to descend and reverted to the bad habits of the beginner pilot.

A trained pilot always allows an airplane to descend in a measured way, much as a balloon drifts down and down as it makes its slow way across a room, but poor instinct tells the beginner pilot to land by pointing the nose of the airplane at the runway like a dart. Now, the one certain result of pointing the nose at the runway is to make a fast plane fly that much faster. So at the exact

moment in time that I should have been slowing down before locking the plane in to a consistent airspeed, I was speeding up.

You can just imagine Tom sitting next to me, wondering what on earth I was doing. He was beside me when, just a moment ago, I had executed any number of simulated engine-out landings. I hadn't been aiming at the runway then. What had come over me? "Don't nose down," he warned me. But I continued to nose down. I wasn't listening to him. In my ignorance and confusion, and with the confidence I had acquired doing those simulated engine-out landings, I must have believed I had it all under control. "Bring the nose up," he said to me a second later. I'm not sure I even heard him. "Nose up now!"



LEARNING

TO FLY

4 OF 4

"A MISTAKE GOES UNCORRECTED," MY INSTRUCTOR SAID, "AND IT SNOWBALLS UNTIL YOU'RE OUT OF OPTIONS."

he demanded. But I continued to nose down until he had no choice but to override me on the controls and save us from the consequences of what would have been a very bad landing. “I don’t know what I was thinking,” I said to him later. He replied, “I don’t know why you weren’t responding to the prompts I was giving you. I said them several times before I did anything about it myself.”

If I couldn’t even hear the man when he was next to me in the plane, what would have come of me if he had not been there at all? At any moment, it seemed to me, my mind might fix on the wrong idea, the wrong approach, the wrong solution, and on a solo flight, with no one in the plane to override the controls, I would drift unwittingly into an accident chain that I would not be able to pull myself out of. “Something goes unnoticed, uncorrected, unaddressed,” Tom once said about the accident chain, “and it snowballs until you’re out of options.”

The accident chain as a metaphor for death in general does a decent job of describing how my father died: The pancreatic cancer that he had, by some miracle, outlived for seven years after his initial diagnosis had set into motion a chain of surgeries and illnesses that in time got the better of him and, with the return of tumors to his lungs, wiped him out. I loved my father a great deal. All my life he protected me and cared for me as no one else had, and watching him die had a profound impact on my mental and physical health.

I didn’t know it at the time, because I believed I was looking death in the eye bravely and maturely, as only the happiest people do, but death is insidious in all sorts of ways. The world in which my father was unable to be reached at any time of day or night for support or comfort was not a recognizable world, and I started having insomnia and anxiety attacks. I woke up every two or three nights just a few hours after nodding off, my heart racing, unable to catch my breath, and still menaced by the final frames of some lingering nightmare. I had an anxiety attack on a stage in Canada and at the historic Piazza del Campidoglio in Rome before an audience of a thousand. Instead of considering that I might be suffering from grief, I attributed these attacks to my own demise.

You see, I’d watched my father so closely in those final days, seen him waste away and grow incoherent with no recourse or reprieve, and the close study made me paranoid. Death was pitiless and indiscriminate; if it could come for him, it could come for me. I must be dying. My death was manifesting itself in sleeplessness, anxiety, and odd little ticks that interrupted my sleep. I went to doctors to confirm the news, and when they gave me clean bills of health, I knew sly death had done something to elude them.

The truth is, I was a mess. I wasn’t taking care of myself. I wasn’t eating right. I wasn’t exercising. I was drinking too much. And I was having those attacks and nightmares. You think you’re safe in sleep, you think you’re beyond fear, but the reeling mind is most vulnerable a few hours after midnight. I would wake to the middle of a living nightmare: no one else awake, no one even stirring, the absence of my dad rendered absolute and universal. I was like a man in solitary confinement from two in the morning onward, nothing to do for hours but watch the unrelentingly black windows for the gray to creep in. And then I would go fly.

That was the flow of my days and nights: nightmare, insomnia, anxiety, flight. Flight, anxiety, exhaustion, nightmare. Grief vibing throughout. I should have quit, and thought about quitting many times, but I had agreed to write about the experience for *Popular Mechanics*, and they had already put out quite a tidy sum to get me where I was. Plus, I had never quit anything in my life. Also, it was possible that I was improving. Tom seemed to indicate from time to time that I was improving. I couldn’t say one way or another, as I could concentrate only on my mistakes and bad habits. I seemed, in fact, capable of dwelling only on the negative, the morbid, and the



fear, which confirmed for me that, when provided with something fun to do, like learning to fly, my looping, stunted, amygdala-heavy brain managed to make it a total drag.

Earlier in the year I had gone to Antarctica, another fun and rare adventure that had nevertheless proved trying in the extreme at various points over the course of our twenty-one-day expedition. In particular, I was dismayed one night when, at the helm of the ship, the Dutch tall ship called the barque *Europa*, I accidentally steered the wrong way right at that moment in time when the wind, which had been virtually nonexistent for several hours, finally picked up, allowing us at last to make good time through the Drake Passage. I was as eager to do so as everyone else, but I got confused by so simple a thing as the wheel, and mistakenly believing that I should steer clockwise in order to keep us on the correct heading, I went clockwise, and soon the sails began to luff. The captain, who was at the bow, came running back, demanding to know what I had done. “I screwed up!” I cried. Should a person incapable of operating so analog and straightforward a thing as a wheel on a boat allow himself to go up alone in an airplane? I didn’t think so.

But as I say, Tom seemed to indicate from time to time that I was improving, so much so that one night after practice I heard him say to me, “Don’t dawdle on the medical.” Now, a medical is an airman’s physical, which the FAA requires the novice pilot to pass before taking his first solo. Tom was telling me that with my medical in hand, he could extend the invitation for me to solo at any time. He took it on faith that I wanted to solo, whereas I really hadn’t yet made up my mind. I felt no more fear, or very little fear, anyway. I was comfortable in the cockpit. I was proficient at the controls. I might have stopped myself right then and asked, “How did I get here?” Because for so long none of that was true: I was neither comfortable nor in command. But here is the truth: I, the scaredy-cat, the little mimsy



LEARNING

TO FLY

4 OF 4

boy, had learned to fly. Anything is possible in this world. Anything. Don't get me wrong: My landings still needed to be more predictable and consistent, but that was just a matter of practice.

So the question came to me: Was the decision not to solo a matter of principle, even a superstition? Was I rigidly opposed to going up on my own under any and all circumstances, or was I flexible enough to reassess the situation in light of new information, namely, my improved proficiency and Tom's own confidence? Tom wasn't about to let me go up on my own if he didn't consider me capable. His life wasn't on the line, as mine was, but everything else—his livelihood, his teaching career, the reputation of his flight school—was. He wasn't cavalier about the decision. I could take great encouragement from his remark not to dawdle with the medical. Still not knowing if I could in fact solo, soon after Tom's remark I saw a doctor, Dr. Schneider, for my airman's medical.

I also decided that I needed to do something about how I'd felt since my dad died, when my first bouts of insomnia hit. During critical moments of flight, Tom would encourage me to "get organized." By this he meant that I needed to settle the plane down: level the wings, address the rudder, adjust the speed, ease the climb—whatever was needed to steady her out in order to continue on a path toward straight and level flight. It was like that for me personally. My fears were unsteady my mind. My mind was attacking my body. My body was indulging its worst appetites. Those appetites were disrupting my sleep. My sleeplessness was compounding my fear. I was falling out of my own personal sky. It was time for me to get organized.

The first thing I had to do, I thought, was stop drinking. A lot of grief came from my drinking, not so much that you would call me an alcoholic but enough to wonder what my life would be like without it. For one thing, I thought it might help me sleep better. So at the beginning of November, just as I turned forty—I mean the day I turned forty—I gave it up. I slept better immediately. My anxiety load dropped. The nightmares went away. I no longer drifted off during unrelated conversations into morbid reveries of all the ways I might die during a solo flight. More sleep and less anxiety, and a therapist to help deal with the grief, together with quitting drinking, pushed back the specters and phantasms that had been creeping up on me for months. The whole breathless worry of death abated just a little.

HAD MY FIRST SUCCESSFUL solo flight on December 26, 2014, nearly five months after I began my flying lessons. I still can't explain why I decided to solo any more than I can understand why I agreed to learn to fly, unless it is to say that I could solo, just as I could learn to fly, and like the man who looks at the bird and senses the possibility of human flight, what is possible is often simply what is done. That is the human record, to the world's delight and the world's dismay.

I don't want to oversell it, but if I needed any reassurance that year that I was not dying as my father had died and that I had things to live for despite his painful absence, I found it that day in front of the double lines of the runway waiting for clearance from air traffic control, when I knew that despite being hobbled and despite being anguished, I had prevailed over my grief and my fear and overcome a not inconsiderable amount of technical challenge to prove to myself that I was still mentally sound and ticking. I was in Six-Two Romeo absent all expertise and guidance but my own, and took her up in the air by myself without reservations or second thoughts, and as I circled the pattern, I whooped with happiness and pumped my fist in victory and failed to repress a smile so insistent that it began to hurt my face. It was absurd but true: an unrelieved and cheesy smile was the closest I came to hurting myself during my solo. It was such pure, undiluted pleasure to be up there on my own, a long

brain bath of endorphins and joy, much more fun than I had anticipated. It wasn't until then that the fuller story came into view.

I'm not simply someone who takes a fun thing and turns it into a drag. Matters of life and death, which are the only things worth considering, demand to be taken seriously, and must be wrestled with as Jacob wrestled with the angel, and when at last the struggle is over, you have truly earned something, and your happiness is not easily acquired or short-lived, and not likely to be forgotten in your lifetime.

"I always tell people," Tom said to me more than once, "it's a lot of fun, but it's not a game."

"With me," I once replied, "you could have said, 'It's not a game, but don't forget, it can also be a lot of fun.'"

Because the fact is, I had to work at having fun inside the airplane as much as I had to work at controlling my rate of descent or reading the aviation maps. Mindless testosterone fun was not my way. Deliberation was my way. Overthinking was my way. Fun did not come to me inside Six-Two Romeo until I had earned it through mortal worry. Only then could I whoop and holler like your average flyboy buzzing the towers of New Jersey.

After three takeoffs from Caldwell Airport and three full stops, or about forty minutes of solo time, I picked up Tom at the apron on my way back to where we parked Six-Two Romeo. I don't hesitate to say that I wanted to please and impress Tom. Your flight instructor sees you at your worst, day after day at your mincing, anxious, hesitant, erring, stubbornly confused, unconfident worst, so when at last you do something worthy, you feel like a little boy longing to be celebrated for his bravery and triumph.

And Tom knew how scared I had been. Before our very first lesson, in the wake of grief, deprived of sleep and personally disorganized, I had confessed to Tom that I might be slipping.

"What are we talking about here?" he asked. "Are you putting your pants on backwards?"

He looked at me, waiting.

Because we didn't yet know each other, and because I had basically just walked in off the street and confessed that I might be slipping while also proposing to go up in the air with him and pilot around in his airplane, I felt the need to walk my comment back.

"No," I said. "Nothing like that. I think it's just because I'm turning forty."

I explained it away as a simple matter of aging. But over the course of my time with Tom, as we got closer, I took him into my confidence. I told him the extent of my fear of flying, and I told him about my dad and my months of grief.

When he got back into the plane with me after my solo and we parked Six-Two Romeo, and the propeller wound down and we removed our headsets, he turned to me and half-smiled and said with pride something I'll never forget, which pretty much nailed the feeling I had just then, and the feeling I hope to keep alive in me for many years to come.

"Long way from terrified," he said.



Go to: POPULARMECHANICS.COM/FLYING For rules, see page 41.

HOW IT WORKS

DESALINATING OCEA

WHEN DEAN SPATZ began his introduction-to-engineering-design class as a sophomore at Dartmouth in 1963, reverse osmosis, the process of filtering water through a semipermeable membrane, was only four years old. Working with a team, Spatz used RO to create a prototype for turning undrinkable brackish water into a potable liquid. The commercial applications were obvious, and Spatz dedicated the rest of his time at Dartmouth to developing the nascent technology. After graduating, he founded Osmonics, Inc., one of the first reverse-osmosis companies, in his garage in Minneapolis.

Today reverse osmosis is vital to a wide array of industries. "It's absolutely astounding that it's happened so quickly," Spatz says. By far its most common use is in desalination plants, which convert seawater into drinkable water. Later this year the 250,000-square-foot Carlsbad Desalination Project near San Diego, the biggest plant in the Western Hemisphere, will begin creating roughly 52 million gallons of freshwater per day. At the heart of the plant is RO technology supplied by General Electric, which acquired Spatz's Osmonics for \$253 million in 2003—just 40 years after he and his team developed their first prototype.

—ANDREW DEL-COLLE

1 FLOCCULATION CHAMBERS

Before the seawater can be filtered, it's destabilized in a process known as flocculation, using a coagulant such as ferric sulfate to bind microscopic particles. In the chambers the water is agitated for maximum coagulation.

2



MULTIMEDIA FILTRATION TANKS

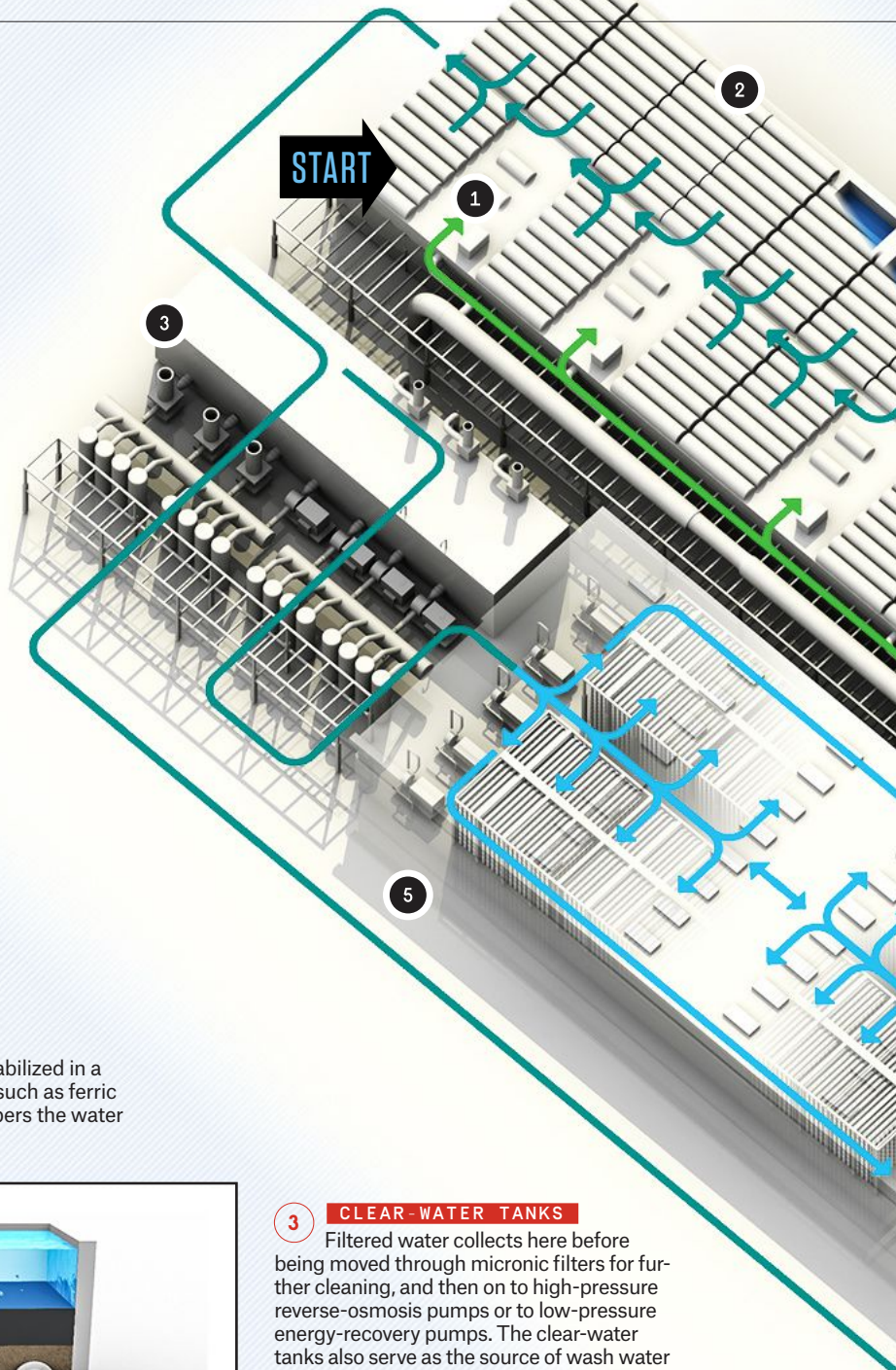
After flocculation, the seawater is moved to 18 multimedia filter tanks. Each tank is made of steel-reinforced concrete and contains 1-meter layers of anthracite and sand resting on a bed of gravel. Each layer filters out organic matter and particles before the water exits through a drain in the bottom of the tank.

3 CLEAR-WATER TANKS

Filtered water collects here before being moved through micron filters for further cleaning, and then on to high-pressure reverse-osmosis pumps or to low-pressure energy-recovery pumps. The clear-water tanks also serve as the source of wash water used to clean dirty filter tanks.

4 WASTE-SOLIDS-DISPOSAL BUILDING

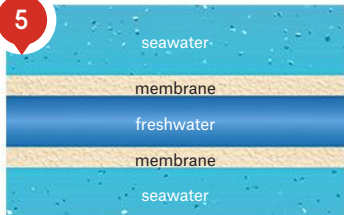
The wash water used to clean the filtration tanks is run through lamella clarifiers (inclined plates that capture particles) and then on to centrifuges atop the disposal building to be separated into semiclean water and sludge. The water is recycled, while the sludge is turned into solid filter cake for truck removal.



N WATER

California's Carlsbad Desalination Project, which will start operating later this year, will process more than 104 million gallons of seawater daily, turning about half that into drinking water. Such a huge operation requires an immense amount of energy, so efficiency is key.

5



REVERSE-OSMOSIS SYSTEM

This stage accounts for 85 percent of the 10 kilowatt-hours per thousand gallons the plant uses for desalination. Here, half of the clear water is pumped through 14 reverse-osmosis arrays at an elevated pressure of 800 pounds per square inch, forcing water through electrically charged membranes and thereby removing most of the salt. The brine left in the arrays—twice as salty as seawater—remains in the system at slightly less than 800 psi. Rather than waste this pressure, the plant recaptures it to perform RO on the other half of clear water routed to the energy-recovery system. The remaining brine is discharged to the sea.

6

ENERGY-RECOVERY SYSTEM

By recycling the pressure used during RO, the energy-recovery system reduces the plant's total amount of power consumption by 30 percent.

7

PERMEATE STORAGE TANK

This is where the majority of the permeate, or post-RO water, is temporarily held while 20 percent is run through a second reverse-osmosis process, further reducing boron and bromide levels. This water is then blended back in with the rest of the permeate to meet water-quality standards.

8

POST-TREATMENT PLANT

At this point the permeate has trace amounts of salt, but all hardness has been stripped out. To reharden the water and make it noncorrosive, a third of the permeate flows through calcite filters in the post-treatment plant to increase calcium and alkalinity levels. This water then rejoins the rest of the permeate.

9

PRODUCT-WATER STORAGE TANKS

After chlorine, fluoride, and ammonia are added, the permeate ends up in the final underground tank, which can hold 2.5 million gallons of water. The stabilized and disinfected water sits for at least 45 minutes before being pumped into a 10-mile pipeline that eventually connects to the San Diego County Water Authority's regional aqueduct system.

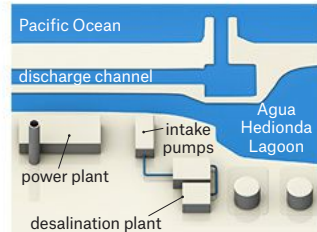
WATER-FLOW STAGES

- Seawater →
- Filtered water →
- Freshwater →
- Brine →

FINISH

INTAKE AND DISCHARGE CHANNELS

Up to 304 million gallons of seawater per day will be pumped from intake channels connected to Carlsbad's Agua Hedionda Lagoon. The channels and the intake pumps were preexisting and are shared with a nearby power plant set to close in 2017. When that happens, a new intake pump will have to be built.





APPENDIX 12 MARINE CHART

POPULAR MECHANICS

Bob Ballard's

ENDLESS VOYAGE

BY

Ryan D'Agostino

SEPTEMBER 2015 ★ PAGE 93

Thirty years ago this month,
he discovered the wreck of the *Titanic*.

He could have stopped there.

And yet today, at seventy-three, he remains the
world's most vigorous ocean explorer.

**An exclusive look on board his ship
and inside his world.**

PHOTOGRAPHS BY

BEN SKLAR

R

Robert Ballard is belowdecks on the R/V *Knorr*, a 279-foot research vessel owned by the Woods Hole Oceanographic Institution in Massachusetts, staring at a bank of screens. He wears a blue cap and a blue shirt and his face is lit by the humming blue glow of the monitors. At forty-three he has completed more than seventy expeditions as an oceanographic explorer and discovered sprawling geologic phenomena, entire species, whole undersea worlds no one knew existed. And now this. Thirteen thousand feet below him, Argo, an underwater search vehicle equipped with a video camera, has captured images of craters—craters that would be inexplicable outside the context of this expedition. Ballard has long been trying to find the wreck of the RMS *Titanic*. So many men have come looking for the unsinkable boat since it sank in 1912 that Ballard has a decent idea where the massive ship is not. Where it actually came to rest on the ocean floor is a much more difficult proposition. Not so much a needle in a haystack as a needle in a haystack at the bottom of the ocean. In his explorations he has found important vessels, and he will go on to find many more, any one of which would constitute a major find, the capstone of a career. But the *Titanic* is orders of magnitude different. The *Titanic* is the Holy Grail.

Of course, the truth is that the *Titanic* isn't even Ballard's real mission. This is not an Ahab situation, and Ballard is not on a quest. Earlier this year the United States Navy asked Ballard, who is a commander in the reserves, to assist in a secret mission to find two nuclear submarines that had been lost at sea for two decades—they needed to determine whether the subs were releasing radiation into the ocean. And they needed Argo to do it. The Navy told Ballard that if he used Argo to find the lost subs, and if he had any time left over before the *Knorr* had to get back to port, they would secretly finance his search for the *Titanic*.

He found the subs, and now here he is in the control room, and images of these impressions on the ocean floor have Ballard wide awake. More than seven decades after the ship's catastrophic collision with an iceberg, could it be that these craters were left by some of its shattered remains?

Argo's camera, the explorer's powerful unblinking eye, closes in. And what it picks up next will alter the course of Bob Ballard's life.

Ballard stands on the stern of his ship, the *Nautilus*, waiting. At seventy-three he stands over six feet tall, he's trim, and his skin is tanned and tight after more than five decades spent mostly at sea. The sun is shining in Galveston this morning, and a breeze drifts across the deck. He's waiting for a group of donors, some of the many financial backers who help make possible his adventures. After a few minutes, an SUV pulls into the vast gray parking lot on the pier next to the ship. A group of Houstonians wearing pressed golf shirts and flowery sundresses has arrived to meet the famous explorer and to get a tour of his ship, and Ballard bounds down the gangway to greet them with smiles and big handshakes all around. He bends at the waist to greet a little girl and ask her name. He leads the group aboard, showing them the way with a large upturned palm and holding the hands of the ladies as they climb from the pier to the deck, gestures he has performed hundreds of times for hundreds of his supporters.

As always he wears his *Nautilus* uniform, the same outfit every crew member on board is issued: navy-blue polo shirt with a gold compass insignia. Underneath it reads E/V *Nautilus*. Not R/V, because *Nautilus* is not a research vessel. Research vessels set out to prove hypotheses, which, if you ask Bob Ballard, can be a little redundant. You're proving something you already pretty much know. No, the *Nautilus* is an exploration vessel, like it says on the shirts: E/V.

He wears a matching navy-blue cap. No name, no rank. All the blue polo shirts and caps are the same. The point is, everybody on the *Nautilus* is important. Fifty-five percent of his staff (his "corps") are women—a Ballard man-

“Man to Mars? Ridiculous. We’ve explored less than 10 percent of the ocean floor. So in my final years I said, Let’s create a ship of exploration that just goes. Because we haven’t been.”





date—and an even higher percentage are students at some stage of their undergraduate or graduate studies in oceanography, geology, biology, archaeology, engineering, or filmmaking. (“You don’t have to pay ‘em,” he says of the students.) You get to issue mandates when you are president of the trust that you created and that owns the ship, as Ballard is. The Ocean Exploration Trust. His trust. His ship. His responsibility.

Money is a frequent topic of conversation for Ballard, because it takes \$10 million annually to keep the *Nautilus* in the water for four to six months every year. (Similar vessels, he says, cost six times that.) Ballard’s unique position as an oceanographer/owner makes him both liberated and beholden. For that money that frees him to explore, Ballard must regularly court private donors, corporate sponsors, and politicians who believe in his mission enough to fight for public dollars. The donors love to hear about the *Titanic*. The politicians are guided by an interest in everything from Ballard’s commitment to education to his exploration of the earth’s crust.

These days, empirical findings have become the slings and arrows in some very nasty and subjective debates. And the scientific method, which has been the wellspring for so much of America’s greatness, now seems to be turning the country against itself. In this atmosphere, Bob Ballard and his relentless quest to master the ocean bottom have, improbably, become the basis for a broad political consensus. Rep. John Culberson, a Republican from Houston and chair of the House Appropriations subcommittee on commerce, justice, and science, has won millions of dollars of financial backing for the Ocean Exploration Program run by NOAA, the National Oceanic and Atmospheric Administration, which supports Ballard’s trust. The congressman is intensely interested in Ballard’s work discovering natural resources in the nation’s exclusive economic zone (EEZ), a collar of ocean floor along U.S. coastlines to which it owns exploration rights. “Dr. Ballard’s the first scientist I’m aware of that’s made a concerted effort to map the EEZ and catalog the mineral resources there,” he says. “China’s cleaning our clock in locking up 97 percent of the world’s rare-earth elements, controlling vital resources, and positioning itself to become the superpower of the twenty-first and twenty-second centuries. So Dr. Ballard is an easy sell to my colleagues, Republican and Democrat.”

After Ballard finishes the tour for the wealthy Houstonians—nice folks, good

time—he is sitting in his quarters, a sparse wood-paneled room above deck with a bunk, a desk, and two framed illustrations from his favorite book, *20,000 Leagues Under the Sea*, on the walls. His phone buzzes with an incoming email. He fastens his glasses, the kind that snap apart at the bridge, and scrolls down.

“Oohhhh, wow. Yes! Yes! God bless him. The House has already . . . now the Senate . . . Yes!”

It’s an email from a contact in Washington. Ballard and his team have been waiting to hear about a major funding request from Culberson’s committee, and the chairman has come through.

“Yes! I just have to sit here for a minute.”

He drums his fingers on the table, his mind racing. Claps a few claps into the air.

“That is absolutely huge. Oh, *man*. Culberson gets it.”

Titanic brought him fame and a little fortune and the promise of a career as long as he wanted one. He wrote a cover story for *National Geographic*, where he was an explorer in residence. And yet it was a discovery of a known thing. Ballard seems prouder of his discoveries of the prizes for which he was not looking—the prizes you win, he says, by spending “time on the bottom.” In 1977 he discovered the very existence of hydrothermal vents, hot springs in the ocean floor near where tectonic plates move apart from one another, releasing a steady flow of superheated water from deep in the earth’s crust. The water is a chaotic mess of mineral-rich fluids including sulfide that, when discharged into the frigid, pressurized water on the ocean floor, can create new ecosystems hospitable to a wild mix of creatures. In the worlds of marine biology and geology, it was a monumental discovery. In the actual world, nobody much noticed.

He discovered the wreck of the German battleship *Bismarck* too. In 1989, in the North Atlantic. He discovered the wreck of *PT-109*, JFK’s World War II boat, in 2002. The naval ships sunk at Guadalcanal. He was first to explore the *Lusitania*. But the *Titanic* is what keeps the people showing up. The *Titanic* is why yesterday three hundred local schoolchildren flocked to the *Nautilus* to meet Ballard and to run around his ship.

“When I found hydrothermal vents, no kid wrote me a letter,” he says. “The *Titanic* was my seventieth expedition. But when I got back from the *Titanic*, I couldn’t see my desk. The mail that came in—they poured it on my desk while I was still at sea. I said, what is this? They said, *it’s kids*. And they were all saying the same thing: What do I have to do to do what you do?”

Ballard thought a lot about those letters. Thought about

what he could do with this knowledge that there were children out there who wanted to be a famous explorer, which he suddenly was. He was forty-three. Born in Kansas into a hard-living family (“My grandfather was shot in a gunfight”) and raised middle class in California, he had become a respected oceanographer and a commander in the Navy. He had clawed through the publish-or-perish tenure process in academia and earned job security at the University of Rhode Island. But now he was the man who had found the *Titanic*, and he would be for the rest of his life and well after his death. He didn’t have to give lectures or coauthor papers. He did, however, want to teach.

The letters from children gave him an idea: With the right technology, maybe he could teach from the sea.

Not just any oceanographer gets to have his own ship. *Nautilus* is a 211-foot former East German research vessel, built in 1967, that Ballard has so far spent \$15 million reconditioning and outfitting as an exploration vessel. It carries seventeen crew and thirty-one scientists and operations specialists. On the ship’s stern sits a winch the size of a Volkswagen that is used for raising and lowering Ballard’s two remotely operated vehicles (ROVs), Hercules and Argus, between the ship and the ocean floor—the winches can release more than forty-eight hundred meters of steel cable into the sea. Belowdecks, he has installed remote command centers throughout the ship—small, darkened rooms with a jumble of screens on the walls that constitute the nervous system of this whole operation, allowing Ballard and his crew to show the world what the ocean floor looks like. Mankind has only ever seen less than 10 percent of the ocean floor, which is not very much at all, if you ask Bob Ballard.

Ballard is usually on board for one month a year. The rest of the time, he is tethered to the *Nautilus* by technology from his home in Connecticut or his office in Rhode Island. He has many more expeditions behind him than in front of him, and that creates a tense urgency in a man. Especially a man who appreciates the coefficient of his mortality, and knows by now that his ambition will outpace his life by a hundredfold, which is a startling discovery all its own. But to watch him aboard his ship is to witness a man possessed by the possibility of what he might find tomorrow. At this particular moment he is standing on the deck of the *Nautilus* in Galveston, 8:00 a.m., the sun trying to burn through a morning haze. In three weeks his ship will steam south through the Gulf of Mexico, through the Panama Canal, and down to the Galapagos Islands, where Ballard will revisit the site of the



ROBERT BALLARD, DISCOVERER

DATE OF BIRTH: June 30, 1942
HOMETOWN: Born in Wichita, Kansas, grew up in Southern California
CHILDHOOD HERO: Captain Nemo
CURRENT HERO: Captain Nemo
PLACE OF BUSINESS (ON LAND): The University of Rhode Island Department of Ocean Engineering, where he is professor of oceanography and director of the Center for Ocean

Exploration
PLACE OF BUSINESS (AT SEA): E/V *Nautilus*
PREVIOUS EMPLOYER: U.S. Navy for 30 years, rising to the rank of commander
UNDERSEA EXPEDITIONS: 140
THE ONE YOU’VE HEARD OF: His 1985 discovery of the RMS *Titanic* 400 miles off the coast of Newfoundland
BUT THAT’S NOT HIS FAVORITE. **HIS FAVORITE WAS:** Uncovers hydrothermal vents and “black smokers” in

the Galapagos Rift and East Pacific Rise in 1977 and 1979; his findings helped scientists learn how life-forms use the energy of the earth through chemosynthesis
MOST RECENT HONOR: Inducted as a Fellow of the American Academy of Arts and Sciences
OTHER FELLOWS: Thomas Jefferson, Albert Einstein, John James Audubon, Alexander Graham Bell

hydrothermal vents and “black smokers” he and his team discovered in 1977.

“You can’t discover unless you’re exploring. It’s *time*. What are you looking at? *A whole lotta nothing*. Turn the corner. *Boom!* We never knew there were black smokers at 650 Fahrenheit coming out—till we turned the corner,” he says. “It’s all about being there so you can get lucky. And you have to do it as cheaply as possible.”

It’s hard to imagine that Magellan ever had occasion to say *Boom!* Harder still to imagine Columbus squiring Isabella aboard the *Santa Maria* to show how her money was being spent. But with every molecule of dry land now surveilled from space, this is how Ballard describes how the *Nautilus* is set up to handle the *boom* moments that come with discovering all that remains to be discovered in the three-dimensional chess of the oceans deep:

“It’s like an emergency room. What’s going to come in on an ambulance to the ER at two in the morning? You have no idea. So, how are you going to deal with that uncertainty? Well, you have some people there to do triage and keep the person alive. But then what do you do when you need a specific expert? You have doctors on call, and you call the right one for the situation: ‘Get in here.’ That’s how we run this ship. When we find something, we call the right expert.”

Ballard has assembled, over the years, an astonishing roster of experts in many fields, all volunteers. When the *Nautilus* is at sea, towing its cameras through the depths, and it finds something interesting, the crew needs to know whether to stop and explore further or move on. And they can’t keep fifty experts on board at all times. So the *Nautilus* has a phone system with a 401 area code. “The ship thinks it’s in Rhode Island at all times, no matter where on the planet it is,” Ballard says. “When we need an expert, we just pick up the phone. It goes like this: ‘Hi, Deb? I know it’s 2:00 a.m. on Sunday morning, but can you boot up your laptop? *We got something. We wanna know what it is.*’ The ship is hovering in twenty thousand feet of water wondering, up or down?” And we do this literally all the time. All. The. Time. Within twenty minutes we have to deliver the brightest mind in America on whatever subject it is to the spot of the discovery to tell us what to do. If you tell us *go*, we go into a response strategy,” Ballard says, jutting his chin into the breeze. “It’s an unbelievable feeling. The closest thing to a drug for me is Coke Zero. I don’t drink coffee, I don’t smoke. I do have wine. But you can’t beat the thrill of finding something on the bottom. And I’ll wait and wait and wait for it. We just had one on the last trip!”

That one went like this:

“We’re down in the Lesser Antilles, in Grenada. A volcano called Kick’em Jenny is down here. Two plates going at it. It’s the only active underwater volcano along the Lesser Antilles. We’re looking at it, and we have this brand-new sonar on the ship that can make amazing maps—\$3 million mapping sonar, because you need maps. We can go to any place on the planet and make digitized maps of the ocean floor.

“We noticed that Kick’em Jenny collapsed in itself and set off a big avalanche. Okay, big deal. Volcanologist says, Okay, but I wanna go down to the bottom of the avalanche and pick up some rocks. Fine. Well, it’s the last day of the *season*, we



^

Clockwise from top right: Ballard in Woods Hole, 1982; the “black smokers” he and his team discovered in the Galapagos; navigating the *Knorr* in search of *Titanic*, 1985; Ballard (in hat) on the nuclear submarine NR-1 searching for geothermal vents near Iceland for *National Geographic*, 1985.



had done everything we wanted to do. We told the *National Geographic* film crew to leave. We were doing a show, they had been with us for four months, but we told them we were just gonna go down and pick up some rocks. What do you expect to be down at the base of an undersea landslide? Rocks. But! *Surprise*. We head down the hill and we come across this river coming out of the side of the avalanche. What is this? *It’s a river*. I know it’s a river, dummy, but how do you make a river in an avalanche at the bottom of the ocean? And it’s funny-colored. And it’s pretty violent. We *ran* up to the command center.

“It starts off acting like an avalanche. But then—what’s that? I dunno. Never seen an avalanche leak. It’s like someone took a knife and cut across it. We’re seeing all these shells and black stuff . . . an entire community of life here! It’s chemosynthesizing”—chemosynthesis being the process of microorganisms creating energy brought about by chemical reactions rather than the sun, as in photosynthesis. “Worms, brittle stars. This is at five thousand feet. I’m feeling very stupid right now. Gigantic mussels. Fourteen inches! Weird parasites living in them, bleeding blood, ghastly—like *Tron*!”

“We said, *Whaaa?* Working hypothesis: We’re off the Orinoco, which is the Mississippi of South America. Full of organics. And the avalanche squashed it and squeezed out methane—we *think*—and they’re using chemosynthesis to process the methane into energy. Well, we had about a thousand scientists on the phone in twenty minutes. And they all said, go down! No one had ever seen this. How many avalanches are there in the ocean? Lots. But no one had ever gone down the bottom of an avalanche to *see*. So how many of these things have we missed? *Lots*. It’s like Christopher Columbus coming back with this thing and saying, ‘We’re calling this a pine cone.’ Well, how many do you think there are? *Lots*.”

It was a major discovery.

Ballard steps back, leans on the gunwale of his ship, shak-

ing his head just a little in amazement. His eyes are wide open. Behind them, his mind is somewhere else. His mind is five thousand feet under the Atlantic Ocean, off the mouth of the Orinoco River.

"You can't beat that."

Time on the bottom.

Long ago, long before even the *Nautilus*, Ballard had figured out how to teach from the sea. In 1989 he launched the JASON project, an ocean-centric educational initiative that has reached more than fifteen million American schoolchildren. (JASON Jr. was the submersible vehicle Ballard piloted to explore the *Titanic* itself in 1986.) At the center of his vision is an experience known as telepresence, which uses a mash of technologies to create a hyperreal version of virtual reality, in which a person has the sensation that he or she is on the bottom of the ocean—or in a rain forest or a desert, or on Madison Avenue—when in fact the environment is being re-created around him using high-definition projection and sound capture.

James Cameron, who first met Ballard in the late 1980s at Woods Hole and whose path would cross Ballard's again when he directed *Titanic* the movie in 1997—he calls Ballard "a dynamo"—felt the sensation while exploring the famous wreck, sending remote-controlled cameras inside the ship while he sat inside the Mir submersible. "After several hours inside a small, nimble vehicle, you form a kind of cognitive loop with that vehicle," Cameron says. "You begin to interpret the image you're seeing on the video camera as if it's sensory input of a different nature. You start to get this kind of synesthesia effect, where interpreting the visual image starts to become kind of bodily, sensory input. Your consciousness now seems to reside inside the vehicle, and I remember a very curious sensation. I turned the [remote camera] vehicle to look back at the Mir submersible. I was sitting inside the Mir submersible at the time, but I thought, *oh, there's the Mir submersible over there, far away from where I am*—and yet I was physically in the Mir submersible! My mind had so seamlessly transplanted itself into the remote vehicle that I now thought of myself as being outside the Mir submersible looking back at it. That's how profound the telepresence experience can be."

Nautilus is equipped with telepresence technology, but because most classrooms are not, Ballard delivers to students what he can using the capabilities they have in common. Last year crew members aboard the *Nautilus* broadcast five hundred live dispatches—Ballard calls them "shows"—to classrooms, museums, and science centers via interactive streaming video, so students can ask questions and get answers on the spot. Producers at the Inner Space Center at URI's Center for Ocean Exploration and Archaeological Oceanography add video and graphics as the crew talks. The students witness the discoveries, and the trust uses the curriculum—which is free to schools—to attract sponsors who make it possible.

"People don't care about the oceans, really," Ballard says, sitting in his office back at URI, the waters of Narragansett Bay shining out the windows. "This is all about motivating kids to study harder. America is a star-based system. We worship individualism. I'm a star because I found the *Titanic*. Not because I found hydrothermal vents. So okay, go with it. I don't sell kids and parents on the ocean. I sell them being a star."

Every day he's home, around five o'clock Ballard and his wife, Barbara, sit outside and watch the sun set over the Connecticut River. Bob fixes something as an hors d'oeuvre, Barbara pours them each a glass of wine, and they talk about the day. They eat dinner together every night, with their two children too, when the kids aren't at boarding school or college. This family time is essential. Ballard's father is dead ("He was an orphan"), and his mother ("God bless her") is ninety-eight and lives in California, where she cares for Bob's disabled sister, who is sixty-eight. His brother died of Crohn's disease a few years ago. A son from a previous marriage was killed in a car accident, a devastating loss that Ballard can't really talk about. Family is important to Ballard, because he doesn't have much.

And yet there are times, after dinner or early in the morning, when Barbara knows her husband's mind is someplace else. She knows his mind is at sea. He can call up his ship's live video stream on its website, nautiluslive.org, any time, even on his phone—anyone can—and instantly he is on board, in the command center, staring at the ocean floor.

"You're not here, are you?" she'll say to him. And he'll just smile.

He works in fifteen-year bursts of creativity. Fifteen-year projects, he calls them. He is seven years into *Nautilus*. And he already knows what he wants to do next. "That'll be my last one," he says. But whatever the project, he is determined to see as much of the ocean floor as he can before he dies. "I got addicted to it. In my fifty-five years of exploring, how much of the ocean floor have I seen?" He holds his thumb and forefinger close together. "In all my discoveries, just that much." His eyes grow wide. "So how much have I *not* seen?"

Back in Galveston, he is standing in the ship's stern, opening a can of Coke Zero, an unfinished one at his feet. "Jeez, I've got one here I haven't even finished yet. It's like a smoker who lights a new cigarette with the one that's still burning."

He sits down in the pilot seat of Hercules, his tanned, weather-beaten hands resting on the robot's massive, shiny claws, not talking, an unusual motionless moment for him on this boat. The Port of Galveston is perfectly quiet. On the channel, a tern is challenging a pelican for the

morning catch.

"My grandmother had all these sayings," he says quietly. "And when I was raising my kids, they started to come out. They've asked me to start writing them down, so I'm doing that."

He is studying the tern as it antagonizes the much larger bird, which seems unperturbed. Their dance is the only movement along the harborside.

"Never get into the thick of thin things," he says. "I love that." He smiles and stares down at the gray water, conjuring other pieces of wisdom.

"Great is the person who plants a tree knowing he will never sit in its shade." He looks up, nods a quick nod, his eyebrows raised. "That's education. That's the long haul."

It's time to go. Galveston is an accommodating way station for the *Nautilus*, but Ballard's team is waiting to go over the plan for the rest of the expedition. Fifty-five years in, the new world below the depths still awaits. PM

SOME SHIPS BOB BALLARD FOUND



Bismarck
Sunk May 27, 1941
Found June 8, 1989



Titanic
Sunk April 15, 1912
Found September 1, 1985



USS Yorktown
Sunk June 7, 1942
Found May 19, 1985



JFK's PT-109
Sunk August 2, 1943
Found May 2002

THE TECHNOLOGY

Then and Now

Robert Ballard's current research vessel, E/V *Nautilus*, was built in 1967, which actually makes it a year older than R/V *Knorr*, the ship he used to find the *Titanic* in 1985. How does that work?

Ballard retrofitted the *Nautilus* with upgrades that help him better explore the depths. Here are a few of the differences thirty years of technological advancements make.

BY CAMERON JOHNSON

1985



► **Flag**
United States

► **Sailing range**
12,000 nautical miles

► **Length**
246 feet, in 1985 (279 after renovations)

► **Lifting capability**
Equipped with a trawl and portable utility cranes

TODAY



► **Flag**
St. Vincent and the Grenadines

► **Sailing range**
13,000 nautical miles

► **Length**
211 feet

► **Lifting capability**
Equipped with a knuckle-boom crane

THE SHIPS

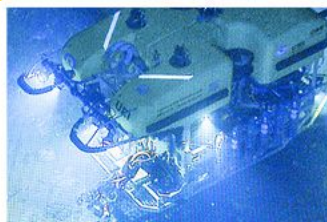
REMOTELY OPERATED VEHICLES

► **Ballard's two ROVs**, Angus and Argo, followed a debris trail to the wreck. They reached depths of 20,000 feet, but with limited piloting capability. Argo provided live video and Angus had three 35-mm color cameras. But the cables connecting the ROVs to the *Knorr* used copper wiring, which is a poor transmitter and

made for bad image quality. And Angus used film that had to be developed.



► **Like their predecessors**, the ROVs Argus and Hercules provide live



video and photos. Both carry high-definition video cameras linked to fiber-optic cables, instantly providing sharp images to the researchers. The crew on board can navigate Hercules with a device called a Doppler Velocity Log that tracks its underwater location, allowing for greater control of the vehicle.

SONAR

► **Readouts for** side-scan sonar were recorded on special printer paper that the crew had to manually annotate with coordinates and time stamps. Then, in a process known as mosaicking, the team cut and manually pieced together the readouts

with scissors and tape to get a full image of the seafloor.



► **Sonar upgrades** mean that programs can instantly provide high-resolution visuals. And mounted on the *Nautilus's* hull is a multibeam echo sounder that allows the ship to create a 3D map of the seafloor up to depths of about 23,000 feet.

ONBOARD SCIENTISTS

► **When Ballard** was searching for the *Titanic*, he was limited in assistance to the 26 other scientists who could fit on board the *Knorr*.

► **Ship-to-shore** technology—a satellite-based telecommunication connection that's just a little slower than high-speed Internet—allows researchers around the world

to tap into a live feed of the mission and offer assistance, meaning better and faster analysis. Schoolchildren can watch too—and feel inspired to become explorers.

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PROJECT



Justin McMillan, owner and manager at Journeys of St. George Island in the Florida Panhandle, takes the author's new board for a test ride.

HOW TO MAKE ANYTHING

HOW TO MAKE A STAND-UP PADDLEBOARD

Waves or no waves, a stand-up paddleboard will let you walk on water. BY BUCKY McMAHON



PROJECT

There was a time, and a very fun time it was, when surfboard design was the most important thing in my world. I happened to be the perfect age, a surf-crazed 13, during the short-board revolution, when surfboards changed from clunky behemoths to nifty little rockets. And lucky me, I was also the perfect age, a sports-battered 50, when the stand-up paddleboard pulled into port. With the SUP, that crucial and grueling transition from belly to feet is eliminated at a stroke. And there's something about catching a wave while standing up that's uncannily exciting. You can ride them on lakes and rivers as well.

But for all my enthusiasm, I didn't think I could make any surfboard, let alone a SUP, which is a surfboard writ large. I did just enough research to be intimidated by dozens of detailed steps. And then I had the opposite thought, which was that if it floated, it would surf. So, chill. Besides, there are really just two steps: shaping and laminating. Rub it some and slap on goo. The rest, as they say, is ding repair.

SHAPING

At a surfboard-makers supply store, I bought a \$228 SUP blank—a 10-foot 4-inch rectangular slab of expanded polystyrene (EPS) foam with a strip of basswood known as the stringer running through the center. You can also purchase one of these online. Be aware: EPS requires epoxy resin, because polyurethane resin will melt it. (This is important!)

I trucked that blank home and stared at it. It already had a rocker, which is a gradual curve from nose to tail, like the upturn in a boat's prow. A rocker keeps the nose from burying itself in the water while you're riding and also lifts the front of the board under wave power. I could adjust for more or less rocker as I shaped. But first I had to do the rough cut, which you can do with just about any kind of handsaw and a template, much like cutting cloth with a pattern. For my template, I traced a borrowed 10-foot SUP on 30-pound roofing felt with a white pencil. I traced half a SUP lengthwise, I should say, with the machined edge of the felt to be lined up with the blank's stringer. By tracing a hemisphere and doubling it by flipping it, you are assured of symmetry.

With a very sharp 10-inch pull saw, I followed my outline, making a few cuts from the outside edge to the cut line to free up the saw in the curves—a scissoring trick learned in kindergarten. Mostly I was in awe of the saw and its silent, near effortless progress through the buttery-smooth EPS foam.

I could've taken that rough cut, rounded the edges, and had a perfectly functional SUP shape for flat water. It would've surfed too. But I was more ambitious than that. I wanted to take about an inch off the deck—the top part where you stand—doming it gracefully down to perfectly rounded rails (the sides) for smooth turning. I wanted high functionality: speed, control, and maneuverability. I wanted to shape.

Hand-shape, I should specify, unaided by expensive power tools. I picked up the saw again, marking it with tape at $\frac{3}{4}$ inch, and made numerous vertical cuts in the deck to that depth. I had measured and marked the rails for desired thickness ($4\frac{1}{2}$ inches at the thickest point) and made sure to leave at least $\frac{1}{2}$ inch of foam above



The author applying the hot coat in his workshop. Note the drop-cloths: Epoxy is difficult to remove from floors.

the marks. Then I cut in horizontally from the rails to the stringer, lifting off slabs of foam I wouldn't have to shave off later. Essentially, I used the pull saw to do the job of a \$400 power planer. I carved that baby like a standing rib roast, and when I was done I thought, oh my God, what have I done? It didn't look pretty. But I had not yet, I reassured myself, trespassed into the ideal board

MATERIALS

10-foot 4-inch surfboard blank from US Blanks
Epoxy 3000 3-gallon set (includes 2 gallons resin and 1 gallon hardener)
6-ounce 50-inch-wide fiberglass, 8 yards
6-ounce 38-inch-wide fiberglass, 3 yards
SUP handle (installed after shaping, before laminating)
SUP Gore-Tex vent (installed inside handle to allow EPS to off-gas)
Fin box (installed after laminating)
Fin
Leash cup (installed after laminating, for attaching leash to board)
Deck pad (glued to deck after laminating)



that still existed inside that angular debris field.

Somewhat dubiously, I moved on to the next tool—a 14-inch 50-grit drywall rasp. Within 15 minutes I was competent. After an hour I was in love. I was “mowing foam” (as shapers say) in long smooth strokes, albeit at a rate of maybe $\frac{1}{128}$ inch at a time. I put on some rock ‘n’ roll and went into a shaper’s trance, alternating at times between the rasp and a palm-sized hand plane for the wooden stringer. I did some measuring along the way, but not a lot. A surfboard is essentially a spear point for cutting through water, and I believe we all possess a deeply atavistic knowledge of honing such things.

Following up with a lighter sanding block with an 80-grit screen, I polished the foam to an admirable sheen, smooth as a baby’s behind. And I stuck a handle on the side with epoxy.

LAMINATING

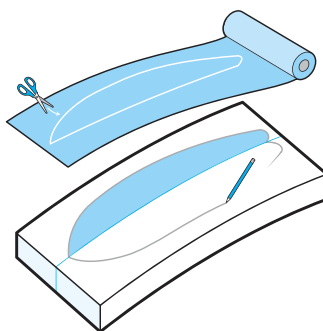
In the real world the shaper and the glasser aren’t usually the same person. The shaper is the rock star, the thinker, the artiste. The glasser is the technician, the dude with the job you don’t want. You can shape at leisure, but once you pour hardener into your resin the clock is ticking. You want to work quickly but not frantically. Good luck!

Before mixing my first pour of epoxy resin and hardener (in a 2:1 ratio), I watched a lot of instructional

A STEP-BY-STEP GUIDE TO YOUR NEW PADDLEBOARD

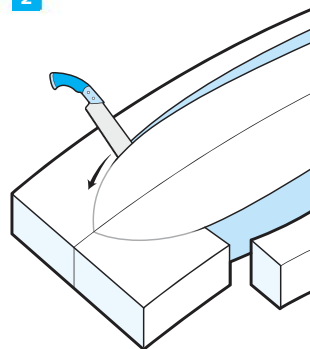
Building a paddleboard is simple in theory, but can be complicated in practice. These are the general steps, but plan to do some research on the shape you like and the tools you want to use before you get started.

1



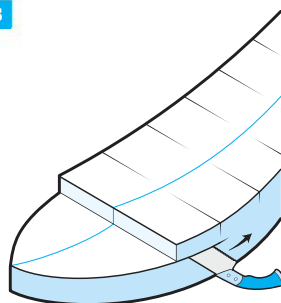
Trace half of a borrowed SUP or printed template onto roofing felt. You’ll flip the felt when you transfer the shape onto the foam.

2



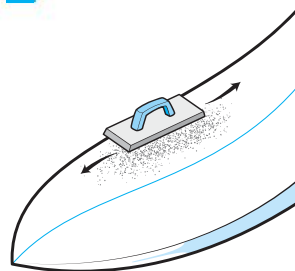
After drawing the shape on the foam, use a 10-inch pull saw to cut around the outline. You may need to cut in from the sides to free up the saw.

3



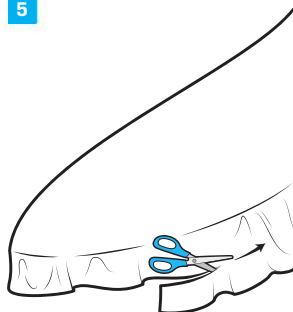
To remove bulk in advance of hand shaping, make $\frac{3}{4}$ -inch cuts into the foam from above, then saw them off horizontally, like a rib roast.

4



Hone the board into shape with a drywall rasp and a hand plane. It should look like a curved spear point, with no rough edges.

5



Cut out three pieces of fiberglass cloth—two for the top and one for the bottom. You may have to fold it at the corners to keep everything smooth.

6



Lay the fiberglass on the board, mix the epoxy, and pour the epoxy over the fiberglass. Spread the epoxy with the included tool.

YouTube, so much so that I was undeniably procrastinating. In the end, your first glass job is a baptism by liquid fire. I survived. My SUP survived. But it was a close thing, at times a bit harrowing.

The weight (thickness) of the fiberglass and the number of layers to be applied are known in the trade as the glass schedule. My schedule called for one layer of 6-ounce fiberglass for the bottom and two layers of 6-ounce on the deck, where you need the most protection. Laminating is akin to tailoring: You lay out the glass on the board and cut so that it overhangs by about 3 inches and wraps around the underside in a snug fit.

This requires darting to accommodate the curves.

You laminate the bottom of the board first, and if you're smart you'll masking-tape the entire deck to protect it from splashes. To laminate the deck, you cut one layer of fiberglass to fit (the easy cut) and then a second layer that goes on top of the first and overlaps by 3 inches (as with the bottom layer). Gently smooth them out by hand, from the center to the tail, and from the center to the nose, until there are no wrinkles. Then pour and spread epoxy over the two deck layers. Having done the bottom the day before, I was already more competent with the little plastic spreader tool. I spread the epoxy with long strokes, listening for a zinging sound that means

the glass is fully saturated. Pull and bring the excess to the rails, and wrap the fiberglass underneath, catching drips in your mixing bucket, repouring excess epoxy where needed.

At lamination's end, to my relief, I found I was somehow well within the parameters of the acceptable. The good news is, if all goes mostly well, there's nothing you can't fix. Lumps can be sanded. Thin spots retouched with a small batch of resin. Ding repair, as I said. After the resin and fiberglass layers have dried completely, in 24 to 48 hours, both the bottom and the deck receive another epoxy layer, called the hot coat. This is also another opportunity to give the board a smooth, glossy finish. Finally, I installed the finishing touches: a leash cup to hold the leash, the fin box, and the fin on the bottom. I glued a deck pad to the deck over where I'd be standing.

My end result (see page 103) was surprisingly successful, admirably light, and nimble in the water. The SUP passed its flat-water test with flying colors, floating a 200-pound test pilot. The surf test awaits. But hurricane season is here, and when the next named storm rumbles up the Atlantic Coast, that SUP will ride the swells. I'm stoked.



HOW TO ADD FINS

A fin is a SUP's rudder, so it needs to be firmly attached. Fortunately, manufactured fin boxes, such as the 10½-inch Fins Unlimited box I used, are simple to add. After lamination, trace the box on the bottom of the board about 7 inches in from the tail and centered over the stringer. A router will cut neatly and quickly through the fiberglass, foam, and wood stringer. To glue in the box, coat the bottom and sides of the slot with a small amount of epoxy, press in the box (wiping away excess resin), and hold firmly for a few minutes.

THE CROSSING

A very athletic office worker paddleboards his way to a personal triumph—and a piece of history. **BY JAKE JACOBY**

It started off easy. I stepped onto my board at 6:42 a.m. in calm waters just off Dionis Beach, on Nantucket, Massachusetts. The brisk wind that was building from the south immediately began to push me toward Cape Cod, about 25 miles away. I scanned the horizon for my escort boat.

My plan was to perform the first known crossing of Nantucket Sound by stand-up paddleboard. I had been waiting weeks for the right wind direction. A south wind would be at my back, helping to push me north toward my goal. It would also allow me to catch and ride (surf) the swells created by that wind, giving me even more speed (and fun) with less effort. In stand-up-paddle parlance this is known as a downwinder or a downwind run.

After months of planning, training, and anticipation, it was time to shut up and start paddling. I was nervous, no question about it. Nantucket Sound is one wild stretch of water. While its status as a sound implies that it is protected compared with the open ocean, all the name really does is provide a false sense of security to the unprepared. Heavy winds combined with shoals and strong tidal currents lead to waves traveling in multiple directions and colliding with one another. Nantucket Sound has claimed many shipwreck victims. Plus, great white sharks have been spotted in the sound off Cape Cod with regularity in recent years. While I knew my chances of being attacked by a shark in these waters were small, I did grow up in the *Jaws* generation. I kept thinking of the scene in which Chief Brody tells Quint, "You're gonna need a bigger boat."

I was also slightly concerned about my lack of training and experience. At the time of the crossing, I was a 41-year-old weekend warrior who spent the majority of my waking hours in an office. Family and work obligations had limited most of my training sessions to less than a quarter of the distance I was planning to cover. I was still recovering from four sports-related surgeries in the previous three years. And I had never paddled in the type of conditions I would soon be facing. The Nantucket crossing would push the limits of my experience, ability, and stamina further than I'd ever been pushed before. But I wanted to test myself—and I really liked the idea of being first.

My safety escort boat finally appeared on the horizon. I began catching and riding the wind-driven swells, linking ride to ride in a way I hadn't experienced before. I would glide for 30 yards or so and then, as the swell passed me by, I would need only one or two strokes to catch the next one. It felt incredible. Ride, paddle-paddle, ride. I crossed the ferry path around mile 3 and continued to head north, regularly checking my course on my GPS watch.

As I moved farther away from Nantucket into less

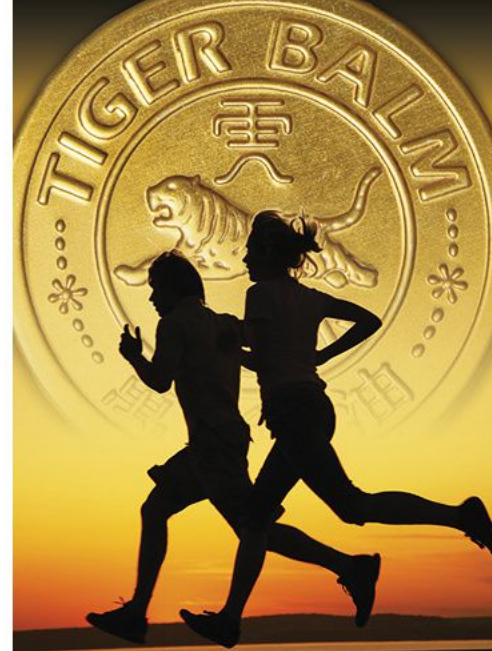


The board was getting whipped around by 20-mile-an-hour winds and shoulder-high swells. I just focused on staying upright.

protected water, the wind began to strengthen and the swells grew. I stayed dry for the first hour and a half, but then had my first fall of the day. I climbed back onto the board and sat for a minute with my legs in the water. It seemed like a good opportunity to eat some energy gel, grab a sip of water from my waist-mounted hydration pack, and take a quick rest. I realized I hadn't turned on the iPod Shuffle I was carrying in a waterproof bag. The music powered me through the next couple of hours:

Johnny Cash, Bob Dylan, the Clash, the Grateful Dead. I did fall a few more times in that stretch, but each fall was a welcome opportunity to hydrate and take a quick rest. I passed the halfway point, and the swells were now between waist- and chest-high. The sea was also more confused, assaulting me from multiple angles. I couldn't see land in any direction.

Then, around mile 14, I felt my first muscle cramp. My upper abdominals began to seize as I climbed back onto the



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board after a fall. I was cramping with more than 10 miles to go. Had I been drinking enough fluids so far? Probably not, but it was too late for that. I lay down on my stomach and stretched my abs by pushing up on my hands. The strategy worked, and the cramp released.

From there the conditions continued to deteriorate into the toughest I had ever paddled in. The wind was now cranking above 20 miles per hour, and some of the swells were shoulder-high and occasionally breaking with frothy white tops. The board was really getting whipped around. I was constantly thrown off balance, which forced me to drive the paddle backward or sideways into the water to keep myself from falling. I became more focused on staying upright than on riding swells. I still caught a few, but the swells were so steep I had to take care not to bury the nose by shifting my weight backward on the board and trying to cut across the swells at an angle.

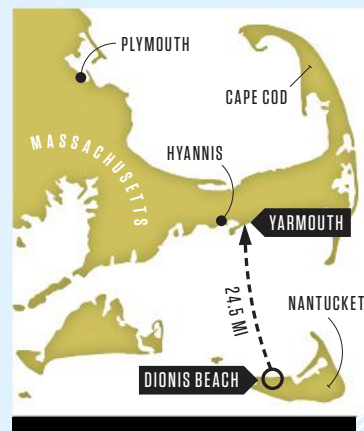
Around mile 18 my escorts pulled up and told me I was too far east. There were rocks all the way from Yarmouth to Chatham, so they wanted me to try to push back to the west, toward Hyannis. I said I would try. I gained a little ground but realized there was no way I was going to make it far enough west to land in Hyannis. I asked if there was a place I could land safely in Yarmouth instead. They said I would probably be okay—but that they wouldn't be able to follow me all the way in.

New doubts began to creep into my head: Would I be able to see the rocks? Would the waves be breaking hard onto the beach? If so, how was I going to be able to get back out to the boat against this wind? Should I have them pick me up a half-mile short of the beach? After all, I would already have crossed the sound. This was just a question of safety and the ability to get over the final few thousand feet. I thought of mountaineers who are sometimes forced to turn away tantalizingly close to a summit. How devastating that must be.

But my plan had been to go shore to shore unaided. I had to try to make it all the way. If I got closer and it looked too sketchy, I would consider bailing.

Then Adam in the escort boat gave me some final words of encouragement: "You might want to keep a better eye out for sharks on this stretch. I think this is close to where some of the great white sightings have been." Uh-huh. I looked down at my feet. They were nicked up and bleeding. I must have cut them at some point while falling or climbing back onto the board. Great whites can smell blood in the water from how far away? I admit to looking around nervously over the next mile or so, but that faded as my goal neared. I was going to make it, and my adrenaline began to surge. I decided that my landing would be a public beach that I saw ahead. Over the last half-mile or so the water was only a few feet deep and the swells laid down a bit, so I was able to catch a few nice, superlong rides. There I was, flying over the water, the bottom clearly visible, covering more than a football field at a time without even having to paddle. A couple of feet from the beach I hopped off, pulled off my leash, and carried my board out of the water. I looked at my watch: It had been six hours and 16 minutes since I had stepped onto the board in Nantucket. I had traveled 24 and a half miles. A lifeguard came up and asked where I had come from. When I told him Nantucket, he was blown away. He offered me some water. I had landed on Seagull Beach in Yarmouth, less than a mile west of my original target.

People will make the same crossing faster, and some may do it with more style. But I will always be the first. Score one for the weekend warrior.





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Shopping List

QTY.	DESCRIPTION
1	2" x 6" x 8' Douglas fir
1	1/4" x 4' x 8' lauan plywood
1	3/4" x 4' x 8' AC fir plywood
8	1/4" x 2" lag screws
1	box 2" No. 6 wood screws
1	box 1/4" No. 6 wood screws
1	grip tape,* standard 9" x 33" size
2	skateboard trucks and wheels*
1	3/4" x 36" birch dowel

*Available at skate shops or ccs.com.

Materials (see next page)

PART	DESCRIPTION
A	1/4" x 15 1/2" x 44" lauan plywood (front panel)*
B	3/4" x 6" x 14" AC fir plywood (crossbrace)
C	3/4"-dia. x 23 1/2" birch dowel (handle)
D	3/4" x 15 1/4" x 30" AC fir plywood (side panels)
E	2" x 6" x 45" Douglas fir (skateboard)
F	3/4" x 14" x 15 1/4" AC fir plywood (bottom panel)

*Fasten to sides, then cut off excess length.

Instructions

● parent only
● parent and kid
● kid only

1. Crosscut the 2 x 6 to make the skateboard (E). Round the front edges and sand the corners.
2. Center and fasten the trucks with four 1/4-inch wood screws.
3. Trim grip tape to a 6-inch width and apply to the top of the board.
4. Use a track saw or a circular saw and straightedge to cut out the rectangles for the panels (D), the crossbrace (B), and the bottom of the cargo box (F).
5. To finish the panels, mark the curved front edge, then cut the curve on each side with a jigsaw and a narrow curve-cutting blade. Use a 3/4-inch holesaw to bore the handle hole through both sides.
6. To assemble the cargo box, drive 2-inch wood screws through each side and into the bottom panel. Put the crossbrace (B) in position and hold it with a pipe clamp across the box, then screw through the sides into the brace. Glue and screw the curved lauan front to the cargo box, then cut off the excess.
7. Crosscut the dowel to length and use a mallet to gently drive

it through the handle holes. Bore a 3/32-inch pilot hole through the back edge of each side of the box, then drive 1/4-inch wood screws into the handle.

8. Clamp the box in position on the skateboard and bore a series of 3/16-inch pilot holes up through

the skateboard into the box bottom. Attach the board to the box with eight lag screws.

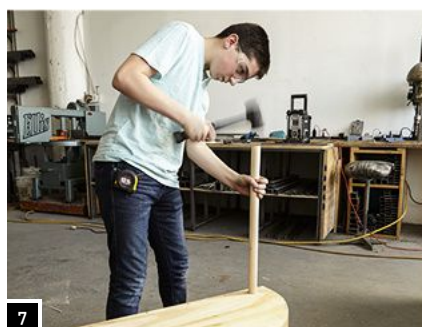
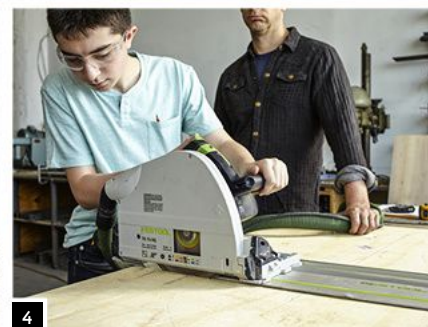
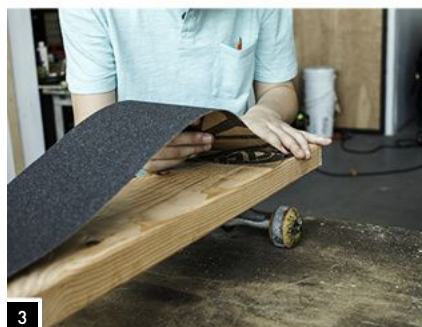
Turn the page for the finished product and schematic diagrams



OLD-SCHOOL SCOOTER

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HOW TO MAKE ANYTHING



SEE PREVIOUS
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INSTRUCTIONS



OLD-SCHOOL SCOOTER!

A project to build with your children.

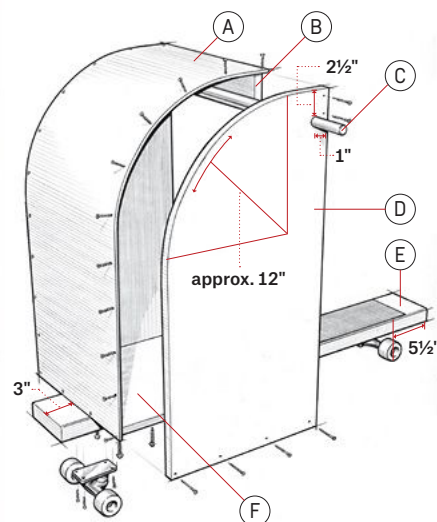
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Difficulty: EASY REASONABLE HARD

Time: 1 hour **Ages:** 12+

PROJECT NOTES

WE WANTED TO RE-CREATE a classic scooter design with a built-in cargo area but with a base of thicker lumber, sturdier fasteners, and a better handle made from a $\frac{3}{4}$ -inch-diameter dowel. The most significant change is our use of skateboard trucks for the wheels, greatly cutting rolling resistance and improving maneuverability. We added stability to the cargo box by running the dowel the entire way through the structure and by placing a 6-inch-tall brace across the back. One other thing to keep in mind: You need a smooth curve on the side panels to prevent the lauan plywood front from cracking. Test-bend the lauan first, and soften the curve if necessary. We built this scooter to fit a child up to about ten to 12 years old. Tinker with the dimensions, though, and you could easily make this suitable for a younger kid. Or even an adult, if you're feeling nostalgic.



Our builder, Sal Castellano, from Staten Island, New York, is a participant in the FIRST Robotics Competition, a nationwide tournament that encourages kids to pursue careers in engineering and technology.



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